PERSPECTIVES ON RISK ANALYSIS AND MANAGEMENT

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RISK ANALYSIS AND MANAGEMENT FOR FOOD SAFETY, SPECIES INTRODUCTION, AND BIOTECHNOLOGY RESEARCH

RISK ANALYSIS AND MANAGEMENT ON NATIONAL FORESTS

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"Perspectives on Risk Analysis and Management at the U.S. Department of Agriculture (USDA)" assembles papers presented by two USDA Panels to the December 1991 Annual Meeting of the Society for Risk Analysis.

RISK ANALYSIS AND MANAGEMENT FOR FOOD SAFETY, SPECIES INTRODUCTION AND BIOTECHNOLOGY RESEARCH:

Risk Assessment and Management for Meat and Poultry by Dr. Marvin Norcross, Food Safety and Inspection Service

A Model for Ecological Risk Assessment for Regulatory Decisions in Field Testing and Release of Exotic Biological Control Organisms by Terry L. Medley, J.D., Animal Plant and Health Inspection Service

Risk Analysis of Biotechnology Research and Development by Richard M. Parry, Jr., Agriculture Research Service

RISK ANALYSIS AND MANAGEMENT ON NATIONAL FORESTS:

The Role of Risk Assessment in Forest Resource Policy by Dr. John Beuter, Deputy Assistant Secretary for Natural Resources and Environment

Risk Analysis for Wildlife Planning and Management on National Forests by Dr. Bruce Marcot, Pacific Northwest Forest Experiment Station and Dr. Hal Salwasser, New Perspectives, Forest Service

Decision Analysis and Alternate Dispute Resolution: Partners in Resolving Resource Management Conflicts by Dr. Lynn A. Maguire, School of the Environment, Duke University

These papers provide a cross-section of the USDA involvement in risk analysis and management as it relates to human health and the environment. The USDA has had a long and broad experience in evaluating and managing risks due to the role risk assessment plays in food, agricultural, and natural resource programs.

The USDA is a research, regulatory, and action agency with specific national policy goals and objectives with respect to food supply, agricultural production and productivity, and natural resource management. For this reason, risk analysis and management have been built into the program planning, decision processes, and environmental impact assessment procedures, and is not considered a separate function. The Department continues to focus considerable attention on assuring that risk analysis is state-of-the art and supported with

the technology and data necessary to quantify the dimensions of the risks in ways that improve decisionmaking and reduce both managerial and public uncertainty.

The USDA panel papers describe how risk analysis and management are embodied in USDA program operations and environmental impact statement procedures as well as how the Department implements risk analysis and manages risk in selected program areas. They also identify and explore various issues involved in risk analysis (information) and risk decisionmaking and the linkages between these two components of risk management.

PANEL

RISK ANALYSIS AND MANAGEMENT FOR FOOD SAFETY, SPECIES INTRODUCTION AND BIOTECHNOLOGY RESEARCH

The beginnings of the USDA role in risk analysis and management date back to the late 19th and early 20th centuries. In those early years, the U.S. Department of Agriculture was delegated responsibilities for meat and poultry inspection, insecticide and fungicide certification, food and animal biologics inspection, and plant and animal quarantine and inspection services. These responsibilities included research and education as well as inspection and regulatory activities. Although not labelled as such in those earlier times, risk analysis and management became a regular part of federal efforts to protect agriculture and the food supply against the hazards of both domestic and foreign pests. It also became a part of our efforts to assure a safe food supply for Americans and other nations importing our produce.

Today, we share some of these risk analysis and management responsibilities relating to the protection of U.S. agriculture and food safety with the Food and Drug Administration and the U.S. Environmental Protection Agency. Nevertheless, the USDA continues to carry out major risk analysis and management activities in protecting both our food supply and consumer food safety. Our newest activity in this area is the Program of the Agricultural Marketing Service, introduced this year, to collect and test randomly selected samples for pesticide residues. We provide the resulting data to EPA so it can have a reliable basis for estimating exposure for risk analysis rather than assuming that residues are always present at the health advisory level. This helps to assure that EPA risk assessments on pesticides can be made more realistic.

Our activities, however, are much broader in this area and today's Panel will describe them for three separate programs.

RISK ASSESSMENT AND RISK MANAGEMENT FOR MEAT AND POULTRY INSPECTION

by

Marvin A. Norcross, Richard A. Carnevale, Jeffrey L. Brown*

The Food Safety and Inspection Service (FSIS) of the U.S. Department of Agriculture (USDA) enforces the Federal Meat Inspection Act and the Poultry Products Inspection Act by ensuring through continuous inspection of food-producing establishments that meat and poultry products sold in interstate and foreign commerce for human consumption are wholesome, unadulterated, and accurately labeled. USDA has been enforcing the Meat Inspection Act since 1906, when Upton Sinclair's The Jungle exposed unwholesome and insanitary practices in the meat-producing industry. In 1957, the Poultry Products Inspection Act was signed into law, requiring that all poultry products produced in the U.S. for interstate distribution be inspected and passed by USDA before marketing. FSIS conducts inspection under these acts with a workforce of nearly 8,000 inspectors and veterinarians in 6,700 slaughter and processing plants nationwide. Every year FSIS inspects approximately 121 million red meat animals, 7 billion birds, and 161 billion pounds of processed meat and poultry products. Scientific support to the inspection process resides primarily in Washington, D.C. but also in several other locations where scientists in many disciplines plan and assist the implementation of new inspection techniques for the control of four primary hazards: microbiologic contamination from pathogenic bacteria; pathologic defects from diseased animals; drug and pesticide residue adulteration; and physical contaminants from foreign materials. In addition, inspectors watch for general insanitation associated with pest infestation in meat and poultry plants.

In order to perform its mandated tasks, FSIS has engaged in the evaluation of risk, an exercise comprising the disciplines of risk assessment, management, and communication. (These three actions, taken together, are often termed "risk analysis"). Risk assessment involves hazard identification and characterization and exposure characterization, leading to a summary conclusion about the likelihood of disease or injury and the significance of effects that would result from exposure. Risk management employs the information from risk assessment to decide what actions should be taken to reduce or eliminate a risk, and how to design and implement policies and strategies to achieve the desired result. Risk communication is extremely important, both in informing the public and affected groups of risks and how best to protect themselves and in educating the public as to the difference between perceived risks and those validated by scientific studies.

Since 1906 USDA inspectors have been conducting daily risk assessments and managing risks associated with these hazards by sorting out those animal carcasses and processed products that do not meet specific standards of wholesomeness and non- adulteration.

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Over the last decade, FSIS has increasingly employed statistical approaches and modern scientific and technological tools to achieve the Agency goal of scientific, risk-based inspection. In addition to the more traditional animal-by-animal inspection, comprehensive programs have been established to monitor risks from drug and pesticide chemical residues and specific microbial pathogens to assess the frequency of exposure of the human population to these hazards. These assessments have provided the basis for risk management interventions employed to reduce exposure to these agents.

In 1985 FSIS asked the National Academy of Sciences to review the meat inspection program conducted by the Agency and make recommendations for an optimal inspection system. A comparable evaluation was conducted for poultry inspection in 1987. In keeping with established definitions of risk analysis, the Academy identified the elements of an "optimal meat and poultry inspection system." Central to such a system, the NAS affirmed, is scientific risk assessment and management: All public health risks addressed by the inspection program's major efforts should be assessed.[1]

Formal assessments will enable the Agency to judge the effects of proposed changes. For example, the major human health risks in poultry are those of microbiological contamination. Therefore, efforts must be made to assess how changes in inspection might affect bacterial risks. Similarly, a thorough quantitative health risk assessment will make it possible to know whether the proportion of resources committed to poultry slaughter is justified with regard to the much smaller amount devoted to residue control. If the present allocation of resources is determined not to be the best use of resources to protect the public health, then the scientific and technical base has been laid for appropriate changes.

The NAS noted that this kind of rigorous overall risk assessment requires considerable time and resources. However, even a finding that needed data are seriously inadequate may have much value in avoiding unjustified changes and in pinpointing needs for prompt data development. More precise data are required before true quantitative assessments can be made of ill-defined hazards such as pathogenic bacteria on raw meat and poultry. Because of the ubiquitous and unavoidable nature of bacterial pathogens in animal-derived food, along with the consumer's ability to cause an increase or decrease in bacterial populations, it is difficult to quantify risks from exposure to specific levels of contamination. Research is needed to more accurately characterize the infective levels of pathogenic organisms, as well as to characterize the risks associated with various handling and processing steps. Such research would make possible the assessment of true risks and the purposeful and accurate targeting of risk management strategies.

RISK ASSESSMENT AND MANAGEMENT PRACTICES IN FSIS

It is important to note that risk assessment as commonly understood involves the balancing of risks against the socioeconomic benefits offered by an innovation. Something very like this is done by the Environmental Protection Agency (EPA) when they review registration petitions for pesticides. But in the case of FSIS, the question of socioeconomic benefits

does not and cannot arise. The Agency is formally charged with maintaining standards of wholesomeness and non-adulteration; it cannot tolerate any additional risk, no matter what socioeconomic benefits would accrue to industry, consumers, or Agency budgets. Innovations are assessed for risk in order to determine if they would in any way add to the risk posed by recognized hazards such as adulterating residues and pathogens. If an innovation in the inspection process decreases risk or is risk-neutral, then it may be accepted. Thus, FSIS risk assessments are limited and internal, intended primarily to identify potential risk situations where action may be necessary and to allocate resources where the risk is greatest.

FSIS has applied risk assessment and management principles for many years in its National Residue Program (NRP), which monitors and controls potentially harmful drug and pesticide residues in meat and poultry. The potent biological activity of many of these compounds raises concern regarding the potential hazard to human health. Exposure of animals to environmental contaminants, or the use of pesticides or animal drugs in a way that does not conform with approved uses, can result in unacceptable amounts of residues of these chemicals in the edible tissues of animals at slaughter. The EPA and the FDA establish the acceptable levels or limits of residues (tolerances or action levels) for these compounds in their respective areas of responsibility (pesticides, EPA; animal drugs, environmental contaminants, FDA) and the approved methods of use for specific crops or animals that ensure that limits will not be exceeded. If limits are not established for unavoidable contaminants, FSIS may request that FDA recommend action levels. Tolerances and approved conditions of use for these chemicals are listed in the Code of Federal Regulations (CFR) in 40 CFR Part 180 for pesticides, in 21 CFR Part 500 for animal drugs, and 21 CFR Part 109 for unavoidable contaminants.

There are several hundred pesticides registered for use in the United States; pesticide residues may also occur in meat and poultry as the result of environmental contamination. The number of potential residues from animal drugs is equally impressive. It is not necessary to monitor for residues of all chemicals, since they differ greatly in ability to produce a residue, degree of hazard to health, and potential for exposing the human population to their residues. In deciding where available resources and testing efforts should be assigned, FSIS assesses relative concerns for those residues most likely to present a risk to the public health. Similarly, the allocation of research and development resources must be based on an evaluation of the public health hazard.

FSIS developed a Compound Evaluation System (CES) in 1985 to assist the Agency in the effective management of its resources and residue program activities.[2] The CES was designed to provide the agency with a more systematic approach to the categorization of compounds with respect to their likelihood of occurrence in meat and poultry and their potential impact on public health. The CES was subjected to extensive external review by a tri-agency advisory board, the Surveillance Advisory Team, and published in 1988. The CES addresses the risk of residues in meat and poultry as a function of three major elements: whether a compound will leave a residue, and if so: hazard (adverse effects that may be produced by a given compound) and exposure (residue concentration; duration of

or frequency of consumption of product containing residues of concern). Compounds are ranked in a scheme that classifies a given pesticide, animal drug, or contaminant in any one of 24 categories. Compounds of greatest concern carry a designation of A-1 (high health hazard potential; high likelihood of residue occurrence); those compounds of least concern are designated D-4 (negligible health hazard potential; negligible likelihood of residue occurrence). The letter Z is used to indicate an element of the two-value system lacking the information needed for classification. Care is taken to avoid the use of exact numerical rankings that might suggest a high degree of sophistication possibly not justifiable because of data limitations or the assumptions inherent in the ranking process.

The assignment of a specific ranking is based on a review of information entered in a comprehensive set of CES worksheets prepared for each compound evaluated. These worksheets provide a permanent record and chronology of the nature and extent of the technical and scientific data that were considered. More than one hundred compounds considered within the FSIS National Residue Program have been evaluated using the CES. It should be understood that the rankings are based strictly on data available to FSIS at the time and may well change as additional information becomes available in the open literature, from other agencies, or from the private sector. To further advance the CES effort, FSIS is using outside assistance in the preparation of a series of compound evaluation reports that will provide the basic information necessary to prepare the CES worksheets. To this end, a contract was awarded that calls for the preparation of evaluative reports on 50 compounds of potential concern to the agency. This work is now under way.

FSIS believes that the Compound Evaluation System is sufficiently flexible to permit rapid response to new information that may affect previous rankings and to enable the use of scientific or expert judgement. It must be emphasized, however, that the CES was neither designed nor intended for use in the development of formal quantitative estimates of risk from meatborne residues. Rather, it provides a rational basis for changes in compound emphasis within the National Residue Program and encourages development of analytical methods for important compounds for which no methods exist. As such, the CES serves as a useful guide in the planning and allocation of FSIS Program resources for those residues considered to represent the greatest potential effect on public health. The CES is updated as appropriate to provide the FSIS with a constant, informative, and sound approach to dealing with residues in meat and poultry.

In summary, our basic approach to compound ranking consists of three elements:

1. Determining if a compound can cause a residue; If the answer is Yes, then,
2. Assessing the hazard of the compound, and
3. Assessing the potential for human exposure resulting from the occurrence of a residue in meat or poultry.

A major FSIS initiative relating to risk assessment, management, and communication is the Hazard Analysis and Critical Control Points concept, or HACCP. HACCP entails the analysis of a particular food production process and the identification of key vulnerable

points - “critical control points” - where public health problems could be manifested. This critical control point approach will be the foundation of inspection in the future because it prevents food hazards before they occur rather than remedying problems afterwards. Scientific data will be employed to identify potential food hazards and establish a system to monitor and control those hazards. We intend to test the HACCP concept in plants of varying size and complexity and then evaluate the possible implementation of HACCP to ensure that HACCP is effective, reduces food safety risks, and protects public health. HACCP will shift the burden of producing safe and wholesome product to where it belongs, i.e., on the industry. Only after the evaluation is completed will FSIS make a decision on whether to go forward with HACCP, and if so, how to do so.

A noteworthy instance of FSIS risk management practices is the case of nitrosamines, carcinogenic compounds that can occur in meat when heating promotes the combination of nitrite with amines. In 1978 FSIS reduced ingoing nitrite in bacon and began monitoring for nitrosamines in bacon. Recently, FSIS detected dibutylnitrosamine (DBNA) in hams being tested while reviewing a new industry process using elastic netting, and requested a risk assessment from FDA. The risk of cancer presented by nitrosamines in cured meats for lifetime exposure - based on 12 parts per billion nitrosamines and a consumption rate of 38 grams per day - was found to be 3.7×10^{-6}. This was determined to be greater than the accepted de minimus risk of 1×10^{-6}, or one in one million lifetime risk. Given preliminary testing data, we are now considering whether to initiate a statistically-based surveillance program of cured, smoked/cooked hams processed in elastic netting. This would allow the Agency to collect statistically based data and take regulatory action on product with nitrosamine levels exceeding an acceptable limit, thereby managing the risk posed by the ham nets.

A similar instance of risk management involves benzene in packaging materials. Following reports of contamination of certain lots of cooked beef, we did a risk assessment indicating that health hazards from short-term exposure were below the level of de minimus risk, but that long-term risks might be unacceptable. The problem was managed by attempts at eliminating the benzene source in future packaging. We are developing a protocol for a statistically based survey to produce data on aromatic hydrocarbon residues in all meat and poultry products packaged in plastic film. Thus, our ongoing risk assessment process will give us exposure information necessary to manage whatever risk might be presented by contamination from packaging materials.

CONCLUSION

FSIS intends to develop a formal and open risk assessment process for all significant areas of policy change. For example, if FSIS wishes to make a significant change in inspection procedures, it will undertake a risk assessment along the lines described here and submit the results for peer review to one or more of its own scientific panels and then to the relevant scientific communities before implementation. Similarly, if the Agency wishes to redirect its resources, e.g., to microbiological hazards from other program concerns, it will

attempt to quantify any resulting changes in risk and incorporate these analyses in a proposal to the scientific community.

Our experience has shown that such quantitative risk assessments are feasible, and with continued research into the risk assessment procedure, as well as the requisite data bases, risk analysis will play an ever increasing role in the meat and poultry inspection program. It is obvious that an investment that will substantially add to the impact of each dollar spent on inspection is a good investment indeed.

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A MODEL FOR ECOLOGICAL RISK ASSESSMENT FOR FEDERAL REGULATORY DECISIONS: FIELD TESTING AND RELEASE OF EXOTIC BIOCONTROL ORGANISMS

by

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The Animal and Plant Health Service (APHIS) has responsibility under the Plant Quarantine Act (PQA) of August 20, 1912, as amended, and the Federal Plant Pest Act (FPPA) May 23, 1957, as amended, to regulate and permit the movement of organisms which are or may be plant pests. Some exotic biocontrol organisms may be defined as plant pests, thus requiring APHIS permits for movement and release. APHIS' reviews of applications for release of exotic biocontrol organisms include analysis of ecological risk associated with the proposed release. Specifically, where appropriate, an environmental assessment (EA) is prepared in accordance with the National Environmental Policy Act (NEPA) of 1969, as an aide to the decisionmaking process. The EA provides a template for ecological risk assessment for the biocontrol release decision, and ensures that the full range of risks associated with release of the organism have been addressed and properly characterized. This decisionmaking model may provide a valuable template for analogous Federal permitting activities requiring ecological risk assessment.

This paper will briefly discuss the statutory bases and intent of the APHIS laws and regulations for movement and release of biocontrol organisms; the complexity and uncertainty of ecological risk assessment as compared to assessment of human health risks; and compliance with the intent and procedural requirements of NEPA as a mechanism for documenting ecological risk assessments and assuring informed decisions.

THE PLANT QUARANTINE ACT AND THE FEDERAL PLANT PEST ACT

Classical biological control utilizes natural enemies (competitors, parasites, pathogens, and predators) from the pest's native habitat to restrict pest population growth to lower and thus more acceptable levels within the new habitat. It is based upon the concept that over evolutionary time, most organisms have acquired a complex of natural enemies that contribute to restricting host population growth within their native range (Carruthers and

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Coulson, 1991). Beginning with the 1889 release of 129 imported Australian vedalia beetles in a California citrus grove overrun with an introduced pest called cottonycushion scale, releases and establishment (introduction) of classical biological control have been remarkably successful in controlling numerous weeds and pests, thereby benefitting agriculture, public health, and natural ecosystems (Coulson and Soper, 1989; Howarth, 1990).

Successes in controlling introduced pest species using classical biological control have also stimulated the introduction of exotic biological control agents for native pest species (Carruthers and Coulson, 1991). However, biological control agents introduced for beneficial purposes can also cause damage to the environment as well as significant economic losses in agriculture. Although infrequent, beneficial biological control organisms can and do become pests themselves. Some have even argued that biological control agents cause species extinction (Howarth, 1990). Additionally, introduced pest species are potential hazards to agriculture and the environment that are associated with the interaction and movement into and through the Unites States of people, ships, and agricultural products, just to name a few.

Under the authority granted by the FPPA and the PQA, APHIS regulates the movement into and through the United States of plants, plant products, plant pests, and any product or article which may contain a plant pest. These articles are regulated to prevent the introduction, spread, or establishment of plant pests new to or not widely prevalent (exotic) in the United States. The regulations which implement this statutory authority are found in 7 CFR Parts 300 through 399.

"Plant Pest" as defined by statute, means any living stage of any insects, mites, nematodes, slugs, snails, protozoa, or other invertebrate animals, bacteria, fungi, or parasitic plants or reproductive parts thereof, viruses, or any organisms similar to or allied with any of the foregoing, or any infectious substances, which can directly or indirectly injure or cause disease or damage in any plants or parts thereof, or any processed, manufactured, or other products of plants (7 U.S.C. 150aa(c)).

"Movement" as defined by statute, means to ship, deposit for transmission in the mail, otherwise offer for shipment, offer for entry, import, receive for transportation, carry, or otherwise transport or move, or allow to be moved, by mail or otherwise (7 U.S.C. 150aa(g)).

Specifically, under regulations codified at 7 CFR 330.200, APHIS' Plant Protection and Quarantine administers a permit program which prohibits the movement of any plant pest from a foreign country into the United States or interstate unless authorized under a permit issued by USDA. Permits are an integral part of the programs conducted by APHIS to protect agriculture by preventing entry and establishment of exotic plant pests (Lima, 1988). Permits are authorizations issued by APHIS for movement into or through the United States or interstate, of a plant pest or regulated article. It is not the intent of APHIS to discourage classical biological control activities for research, eradication, or control

purposes. Regulations should prevent or at least mitigate risks and not inhibit innovation or utilization of beneficial biological control organisms. Regulators should neither over-regulate nor under-regulate. Regulation and any mandatory review requirements must be balanced and, to the fullest extent possible, commensurate with risk. The APHIS regulatory structure and its permit requirements are initiated to adequately consider plant pest and environmental risk while facilitating the movement for research and other purposes of biological control organisms.

Comparison of traditional environmental and ecological risk assessment concepts: To carry out its mandate to protect American agriculture and the environment from the introduction of plant pests, APHIS must ensure its decisions are based on the best information possible and on procedures that lead to good decisionmaking. Risk analyses have been developed to organize complex risk information to lead to better decisions (Lave, 1987; Russell and Gruber, 1987).

There have been a proliferation of concepts for risk assessment of research in the environment. An environmental risk assessment has been described as a "scientific enterprise in which facts and assumptions are used to estimate the potential for adverse effects on human health or the environment that may result from exposures to specific pollutants or other toxic agents" (Thomas, 1987). As is suggested by the previous definition, the emphasis of environmental risk assessments has often been human health with much of the discussion being devoted to various environmental routes of exposure to humans of toxic materials. When the emphasis is on potential impacts to the environment or its component parts, rather than impacts on humans, the term "ecological risk assessment" has been used (North and Yosie, 1987). Ecological risk assessment has been characterized as "the development of a formal approach to characterize the scientific knowledge of the risk to ecological systems following exposure to environmental contaminants" (Thomas, 1987).

When ecological risk assessment has been described by some who approach it from a background in environmental risk assessments of chemicals, they have often described ecological risk assessments as being analogous to a series of additive environmental risk assessments. In other words, the approach would be to develop a numerical dose-response curve for each organism in the ecosystem that might be significantly affected. When we consider the great difficulty that has been expressed in developing this type of data for most ecosystems for even well-studied chemicals (Silbergeld, 1987; Cohrssen and Covello, 1989 [p 87 et seq.]; Silbergeld, 1987), the lack of success for this type of additive, organism-by-organism numerical model seems evident.

Another underlying assumption to environmental risk assessment that must be dealt with early on in the assessment process is the assumption that hazard exists. Classical risk assessment protocols have been widely developed and used for evaluation of nuclear power installations (Okrent, 1987) and for the use of hazardous chemicals in the environment (Cohrssen and Covello, 1989). In these applications the hazard is often self-evident in that specific dose-response calculations can be drawn to describe the hazard. The classic

formula for characterizing risk assessment for these types of applications is: Risk = Hazard x Exposure. When the hazard is well understood most of the assessment then is dependent on descriptions of routes of exposure and determination of potential doses as a result of probable routes of exposure. In this model, as a result that hazard is assumed a priori, identification of routes of exposure leads to the conclusion that there is risk. When applied to release of exotic biocontrol organisms this model can greatly overemphasize risk, therefore, because biological interactions are complex and, absent a hazard such as pathogenicity, predation, or competition, exposure may not equate to risk. In fact, exposure may lead to risk to the organism being introduced if the introduced organism serves as a host or prey for the organism it comes in contact with.

When the chemical model for risk assessment is used for ecological studies, as it has been described above, ecological risk assessments are often equated to being analogous to a series of additive environmental risk assessments. That approach sometimes leads to a quantification of a few well-studied interactions rather than identification of likely interactions; the reasons being several. There is in the chemical model an over-reliance on quantifiable measures. Since much of the data base for biological interactions is qualitative and qualitative discussion does not fit into the model, it may be overlooked or under-utilized.

Therefore, many of the models for "environmental risk assessment" or "ecological risk assessment" that have been described are not appropriate to provide models for evaluation of the release of exotic biocontrol organisms into the environment. Such models are often based on oversimplified models that were developed for use of hazardous chemicals in the environment. Many uncritically assume that hazard exists and seek to characterize the risk from that hazard through exposure assessment. Most do not allow for qualitative data based on experience and observation, instead providing principally for numerical analysis.

Basis for predictive risk assessment philosophy for exotic biocontrol organisms: At APHIS we have sought to identify review strategies that will provide a mechanism for support of decisions on the release of exotic biocontrol organisms and the documentation of those decisions. We have avoided over-reliance on chemical models of risk assessment. The environmental analysis used takes advantage of the more flexible, multi-disciplinary approach of the environmental assessment mandated by NEPA.

The NEPA is our basic national charter for protection of the environment (40 CFR Section 1500.1). It establishes policy, sets goals, and provides means for carrying out the policy. Section 102 of Act contains action-forcing provisions to make sure that Federal agencies act according to the letter and spirit of the Act (42 U.S.C. Section 4332). Section 102(2)(c) of NEPA requires all Federal governmental agencies to prepare a "detailed statement" for major Federal actions significantly affecting the quality of the human environment (42 U.S.C. Sections 4332(2)(c); Bausch, 1991). This detailed statement is known as an environmental impact statement. An agency determination that the proposed major action would not result in any significant environmental impact must be supported by an environmental assessment.

Two fundamental principles underlie NEPA's requirements: Federal agencies have the responsibility to consider the environmental effect of major actions, significantly affecting the human environment and the public has a right to review that consideration.

There is a symbiotic relationship between the Federal agencies' consideration of the environmental effect of major action and the public's right to review that consideration. Similarly, there is a symbiotic relationship between the agency's environmental consideration and final agency decision. We must see that two components as not separate spheres, one being mandatorily imposed by law. Instead, we must see these two functions as parts of an integrated whole. The NEPA document is a pre-decision tool not a post-decision tool.

Environmental Analysis and Documentation (EAD) is one of the staffs of Biotechnology, Biologics, and Environmental Protection (BBEP). It has the primary responsibility for analyzing proposed APHIS actions to ensure that they are in compliance with environmental laws, regulations, and statutes. EAD cooperates with all APHIS staffs in carrying out its responsibilities, and serves in a primary support role for the major program activities: Plant Protection and Quarantine, Veterinary Services, Animal Damage Control, and International Services. In examining proposed APHIS programs, EAD first considers the applicability of existing environmental statutes and regulations to the proposed actions.

The environmental analysis that is developed for an exotic biocontrol organism, rather than being a "risk assessment," an "environmental risk assessment," or an "ecological risk assessment" per se, may contain one or several risk assessments. The environmental assessment might be characterized as containing a biological assessment in a specific ecological framework. That is, the biology and natural history of the organism that is to be introduced is carefully examined, both data from the behavior of the organism in its natural environment and specific host range (or other biological test) done in contained environments like the laboratory or greenhouse. The environment expected to be accessible to the organism when it is introduced is described. Predictions are then made about the expected behavior of the organism in the environment in which it is to be introduced. The potential impacts to the accessible environment are described and mitigation procedures for impacts are noted.

It should be clear that this approach is not fundamentally different from the types of review that have traditionally occurred for exotic biocontrol organisms (Lima, 1988; Coulson and Soper, 1989). The principal difference is that the questions are posed more formally than they have been in the past so as to provide a structured review and analysis of the organism, and potential impacts that may occur from its introduction, either positive or negative. The use of the NEPA environmental assessment as the mechanism for this environmental analysis provides the necessary structure for decisionmaking without imposing inappropriate chemical-based models of risk assessment. It avoids the over-emphasis on data that can be expressed numerically that is a fault of some traditional approaches to risk assessment.

The structure of the environmental analysis provides for the following types of questions and considerations. 1. What is the organism? 2. What is the biology of the organism in its natural environment? 3. What are the characteristics of the new environment? 4. What is the organism intended to control in the new environment? 5. What other organisms is it expected to significantly interact with in the new environment and what are the potential outcomes of this interaction? 6. What procedures or controls are available to mitigate any negative impacts identified? It is important to note that the questions are of a form that would allow the use of valid qualitative information as well as quantitative data to provide the answers. The use of these types of questions are described in more detail in the next section and examples are provided.

Examples of the approach to environmental analysis of exotic biocontrol organisms:

1. What is the organism? This first question actually proves more difficult to answer for some organisms than the simplicity of the question suggests. Many exotic biocontrol organisms are isolated from remote areas and often come from groups which do not have a well-defined taxonomy. It is essential that the identity of the organism be adequately established to assure that it is in a group of organisms that is regulated, and that the appropriate scientific literature is being used to identify specific characteristics of the organism, such as host range, potential to adapt to other hosts, relatedness to problem organisms, potential for dissemination, persistence in the environment, etc.

2. What is the biology of the organism in its natural environment? It is important to know what predator-prey, or pathogen-host relationships the organism exhibits in its natural environment. That information, along with information from the scientific literature may suggest the need for additional testing to gather information for predicting the impacts the organism may exhibit in the environment to which it is to be introduced. For example, in evaluating a plant pathogen to be introduced for control of a noxious weed, it would be important to know that in its natural environment the pathogen had a narrow host range specific to the target organism. In this example, information from the organism's native environment and issues raised by the scientific literature for related organisms may suggest specific additional data that would provide a basis for prediction of the organism's interaction in the new environment. Such additional testing might include testing in containment, such as in a greenhouse, or it might involve testing the organism on other potential hosts in its native range.

3. What are the characteristics of the new environment? To fully understand the potential impacts of an exotic biocontrol agent on its environment it is important to have certain information about that environment. For an organism that is to be tested in a small plot of land and is not expected to be disseminated, it might be as simple as to describe the field-test site and the immediately surrounding area. If on the other hand, it was an organism like a rust fungus that has obligate requirements for specific host material but is widely disseminated through spores, it might include any area of contiguous host material, bounded only by sufficiently wide boundaries of geological barriers (such as lakes, mountains or dessert areas that did not support the host), highly managed areas without

host plants (such as agricultural areas), or areas with climatic conditions that would not allow survival of the rust or effective infection of the host.

4. What is the organism intended to control in the new environment? The organism to be controlled must be properly identified, this is rarely a concern because problem organisms such as weeds are often well-studied and characterized. This information is useful in the designing and evaluating appropriate tests for host range susceptibility. Information about the target organism, and closely related species that might be affected by the control organism, and their role in the ecosystem is important to estimate the magnitude of any potential positive or negative impacts from the introduction.

5. What other organisms is it expected to significantly interact with in the new environment and what are the potential outcomes? This is an area where the answers are often only available from specific testing. For instance for an organism intended to control a weed, host range susceptibility studies would usually start with the plant family of the target plant (weed) and systematically examine plants that are more and more distant to the target plant. The extent of testing is determined by experience from other organisms and by the results of earlier phases of the testing (the more kinds of plants that are infected, the more that are tested in this scheme). These studies should include an examination of agriculturally important crops, especially those crops common in the release area (Charudattan, 1990). Also considered is whether the target plant has closely related threatened or endangered species, or the control organism has closely related pathogens that infect threatened, endangered, or nontarget species in the release area. It may not be possible to test every threatened or endangered species directly, but scientific inference can be made.

6. What procedures or controls are available to mitigate any negative impacts identified? Specific limitations of the new environment on biological functions of the introduced organism should be noted. Such limitations could include information like winter temperatures too severe for the organism to survive and over-winter. Should a problem develop that is not predicted it is important to know in advance about control measures that are available. These might include chemical controls such as fungicides or cultural controls such as exclusion through host eradication.

CONCLUSIONS

To fulfill its mandate to protect American agriculture and the environment from organisms which are or may be plant pest, APHIS regulates the introduction of certain organisms, including some exotic biocontrol organism. APHIS must ensure that the decision it makes are based on the best information and utilizes appropriate procedures. The use of the NEPA process as a component in the review of exotic biocontrol organisms provides an appropriate structure for the informed and responsible decisionmaking. This pre-decisional tool allows for flexibility of inputs, including qualitative information as well as quantitative data. The environmental assessment provides a template for ecological risk assessment for

the biocontrol release decision, and ensures that the full range of risks associated with release of the organism have been addressed and properly characterized. This decisionmaking model may provide a valuable template for analogous Federal permitting activities requiring ecological risk assessment.

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RISK ANALYSIS OF BIOTECHNOLOGY RESEARCH AND DEVELOPMENT

by

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ABSTRACT

The new technologies being developed for producing food, feed, and fiber include biological control of pests and genetically modified organisms. Development of these new materials will require evaluation of potential effects upon the environment as well as food or feed safety. Risk assessment procedures currently used to evaluate pest control products have been developed for chemicals, but are not directly applicable to biological materials. This is particularly true where multiple species interactions are poorly described and understood. The Agricultural Research Service (ARS) has prepared draft guidelines for the introduction of six different types of biological control organisms. The guidelines are the first attempt to specify the principles and procedures which must be used for quarantine containment and environmental safety considerations prior to release of exotic organisms such as weed control microorganisms, insect predators, insect pathogens, etc. The guidelines were prepared in consultation with scientific experts and regulatory officials to assist safe development of biological control organisms and to provide a rational approach to analyze the risk posed by an introduced species. Another program on biotechnology risk assessment research was authorized by the 1990 Food, Agricultural, Conservation and Trade Act. This program will address general concerns about the environmental effects of biotechnology to assist regulators in the development of policy concerning introduction of genetically engineered organisms into the environment. Information is presented on the Department of Agriculture's (USDA) implementation of this biotechnology risk assessment research program.

INTRODUCTION

An evaluation process for the suitability of a new technology in the 1990's must consider three general factors: 1) the impact of the problem upon society, 2) the efficacy of the new method to solve the problem economically, and 3) consideration of any other impacts that may occur upon the environment or society. Econometric procedures are available to evaluate societal costs of a problem and a variety of tests can be applied to estimate efficacy and cost competitiveness of new technologies. The absence of a rational framework to evaluate other non-target effects of new technologies is a relatively new concept and frequently leads to consideration of all theoretically possible impacts and even improbable speculation. Adequately responding to these concerns, often poorly described or documented, can raise the cost of new technologies above the threshold of commercial development and can significantly slow, if not impede, adoption by society.

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ARS is the major research agency of USDA. We have a widely diverse research program ranging from plant germplasm to human nutrition that covers a multitude of different subject areas and employs 2,500 scientists working at 122 locations throughout the United States and in 5 foreign countries. ARS prides itself on being a problem solving research organization, which means that the research is not completed until the original problem is solved and put into actual use by producers of food and fiber and the general public. The problem solving may require basic research to identify new approaches to resolve the problem or it may require applied research to adapt technology for specific use.

The ARS research program addresses the needs of a variety of user groups including the producers of food and fiber, the complex marketing system that delivers commodities to the public, the agricultural business network that supports our farmers, environmental interests and the consumer. A significant proportion of our program is directed to respond to the regulatory and action agency needs of USDA. This includes addressing the requirements of the Animal and Plant Health Inspection Service (APHIS), the Food Safety Inspection Service, the Agricultural Marketing Service, the Federal Grain Inspection Service, the Food and Nutrition Information Service and the Soil Conservation Service. The ARS research program is also relevant to the regulatory activities of the U.S. Environmental Protection Agency and the Food and Drug Administration.

This paper will present a brief overview of some of the ARS programs which are related to the regulatory responsibilities of APHIS concerning the effects of biological organisms upon the environment. ARS has not identified the programs concerned with exotic organisms as risk assessment research per se, however they do contain the elements required to identify potential hazards and measures to mitigate adverse impacts on biological systems.

GUIDELINES FOR BIOLOGICAL CONTROL ORGANISMS

The introduction of exotic pests into the United States has been and continues to be a major threat to agriculture and forestry production. In order to prevent entry into the United States of potential exotic pests, the Plant Quarantine Act of 1912 and later the Federal Plant Pest Act of 1957 were enacted. Regulation of these statutes is assigned to APHIS. The most efficient method to control exotic pests has been shown to be natural biological enemies and/or pathogens which have developed with the organism in its native habitat. The demand for biological control of pests using their natural enemies is increasing as agriculture in the United States moves toward pest management systems that are highly specific to the target organism while having no significant impact on other organisms in the environment. Classical biological control has had great success in controlling exotic pests that have entered the United States including the cotton cushinyscale of citrus, alligator weed, and the alfalfa blotch leaf miner. Naturally occurring enemies of these pests were identified, imported and established in the U.S. which continue to give effective control without the use of pesticides or other methods. Successful application of classical biological control depends upon the importation of beneficial

organisms into the United States and appropriate procedures to evaluate the safety of the material in quarantine prior to introduction into the environment.

The general procedure followed to evaluate exotic biological control organisms is to identify the region of the world where the pest has evolved biologically. Intensive surveys are then made of that region to determine pathogens, predators or other factors which suppress the pest population to a level which is not considered to be economically significant. Specimen samples are collected and sent to special ARS laboratories located in countries where the organism is endemic for preliminary screening, purification and identification. Promising biological control material can be brought into the U.S. after receiving an importation permit from APHIS which normally requires that shipment must be made to an approved quarantine facility that specializes in handling those candidate materials. Containment or quarantine of exotic beneficial organisms is required to precisely identify the material and to conduct host specificity studies which may be predictive of its characteristics before a planned introduction into the United States. Quarantine screening tests also assure that the material is free from any contaminating organisms that may have been inadvertently included with the shipment. Host range testing in quarantine is designed to prevent the release of candidate species, such as weed-feeding insects, which might become pests themselves.

Documented and scientific reviewed procedures have not been available to guide investigators on the appropriate practices necessary to identify, import and evaluate candidate biological control organisms. ARS undertook the task to prepare six guidelines for scientists engaged in this research. They are:

1. Proposed Guidelines for Arthropod Natural Enemies and Competitors of Arthropods

2. Proposed Guidelines for Arthropod-Parasitic Nematodes

3. Proposed Guidelines for Invertebrate Natural Enemies of Weeds

4. Proposed Guidelines for Microbial Natural Enemies of Arthropods

5. Proposed Guidelines for Microbial Natural Enemies of Weeds

6. Proposed Guidelines for Natural Enemies and Antagonists of Plant Pathogens and Nematodes.

These guidelines have been prepared to advise scientists working in the area of biological control on the appropriate procedures and safety considerations which have been found to be applicable for biological control organisms. The guidelines are not expected to take the place of the regulatory procedures used by APHIS for the issuance of permits, however they are designed to be complementary to the evaluation process used for issuance of a permit. It should be noted that while the guidelines give general procedures that need to

be observed, each organism is treated on a case by case basis and the degree of safety precautions are heavily dependant on the biological properties of that species in relation to the environment planned for the introduction.

The guidelines are a product of years of experience, documentation and peer review. The contributions of a number of scientists working on this project is too long to mention here, but the coordinating role of Dr. Jack Coulson and Dr. Richard Soper has been critical to get the documents into final form. The guidelines will be available from ARS in January 1992 and will be available to all interested scientists.

BIOTECHNOLOGY RISK ASSESSMENT RESEARCH

The first field test of a genetically engineered organism in California created an unexpected storm of controversy that sent shock waves through the general public, the scientific community and the infant biotechnology industry. Looking back upon that event in the mid-1980's today, one may wonder why did all this occur? However, this firestorm of public concern could take place again if adequate consideration is not given to informing people about the nature of the research being conducted. It may be useful to briefly look at one such field test of a genetically engineered organism which was conducted in full public scrutiny, but did not cause the same community outrage.

ARS has significant interest in using the tools of genetic engineering to speed the development of improved microorganisms, plants and animals. The controversy surrounding the ice minus field test in California sent a chilling signal to our scientists working with modified organisms: that getting material field tested would consume much time and resources and be of dubious scientific benefit. When a private company approached ARS with an offer to cooperate on a study with a modified organism in 1987, it was recognized as an opportunity to learn how field studies should be conducted under intense public scrutiny without sacrificing scientific merit.

The company, Crops Genetics International or CGI, wished to conduct a field test of a genetically modified endophytic bacteria, <u>Clavobacteria xylei</u>, containing the delta endotoxin gene from <u>Bacillus therengensis</u> or Bt (Witt). The bacteria would be inoculated into corn plants where it would spread throughout the vascular system of the plant so that when the corn was attacked by a corn earworm pest, the Bt endotoxin would kill the insect. CGI wanted to test the efficacy of the technology for pest control and ARS was interested in examining the fate, survival and spread of the bacteria. A Cooperative Research and Development Agreement was approved to conduct a field test at the Beltsville Research Center in 1988. Efforts were immediately initiated to get approvals from the Institutional Biosafety Committee at Beltsville, a permit from APHIS and an Experimental Use Permit from the Environmental Protection Agency. A series of meetings were held with elected officials from the State and local governments and the State Department of Agriculture. Several meetings were held with the general public to explain the field test and answer their questions. After all the approvals were received and in the full view of the media, the test

was started. Perhaps it was because no great controversy occurred that this test is not well remembered today, but at the time everyone watched the experiment with intense interest.

The field test was a success from a number of viewpoints, although the modified organism did not show sufficient efficacy to be a commercially competitive pest control product. It demonstrated that the general public will accept genetically engineered microorganisms if they are given an adequate opportunity to understand the principles and reasons for using the technology. It also gave new knowledge about the biological behavior of the bacteria in the corn plant, the mechanism for dispersal and fate in the environment.

More than 100 field tests have now occurred in the United States since these first efforts. We have gained significant experience in the proper use and procedures for conducting tests. The stage is now set for a whole new host of questions about the safety of widespread use of modified organisms.

The Food, Agriculture, Conservation and Trade Act of 1990, also known as the Farm Bill, establishes a new program in the Department of Agriculture for Biotechnology Risk Assessment Research (see Section 1668, 7 USC 5921). The purpose of this program is to conduct environmental assessment research that will address the concerns raised about the environmental effects of biotechnology and to assist regulators in the development of policies concerning introduction into the environment of modified organisms. It directs that a grant program be established by the Cooperative State Research Service and the Agricultural Research Service to provide funding for environmental assessment research of genetically engineered organisms.

It is intended that the research will cover methods to contain modified animals, plants and microorganisms after introduction into the environment, methods to monitor the dispersal of organisms, and procedures to follow the rate of gene transfer between genetically engineered organisms and related wild species. The program will be operated in consultation with the USDA's Animal and Plant Health Inspection Service, the Office of Agricultural Biotechnology, the Agricultural Biotechnology Research Advisory Committee, and the Office of Research and Development of EPA.

This program will be initiated during the 1992 fiscal year using funds generated from a one percent charge against all biotechnology research projects being funded by the two agencies. The USDA is currently in the process of preparing a mechanism for coordinating the development of the request for proposals, a process for proposal review and selection, and the process for awarding funds. A procedure for reporting and monitoring the research will be prepared along with a mechanism for administrative oversight of the entire program. It is expected that projects will address objectives of priority concern to APHIS and EPA.

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PANEL

RISK ANALYSIS AND MANAGEMENT ON NATIONAL FORESTS

The National Forest System is constituted by 156 national forests, 19 grasslands and 15 land-use projects located in 45 States. They total 191 million acres and constitute over 8 percent of the U.S. land base and about a quarter of the Federally-owned lands. They are managed by the USDA Forest Service for a wide range of uses. They produce 15 percent of the nation's timber, provide 5 percent of the nation's outdoor recreation use (263 million days of visitor use), and they accommodate over 80 percent of the total U.S. wilderness use (12 million days of visitor use).

Risk analysis and management has always been an important formalized aspect of national forest planning for protection against wildfires. Risks have typically been assessed on the basis of forest fuel hazard ratings and the likelihood of wildfire occurrence based on weather conditions and type and level of human activities in and around the forest. Early methods were primitive but still quantitative. Today's methods are more sophisticated. Stochastic modeling is now used with expert opinion to determine optimum strategies for fighting wildfires that escape the first attack. For overall program planning, risk analysis is based on a probability distribution for a range of fire severity classes differentiated in terms of rate of spread and fire intensity. This program model is used to estimate optimum program budgets for national forests based on expected annual wildfire occurrence. It is also used to optimize the program strategy for a given budget. In recent years the Forest Service has been extending this risk assessment and management modeling capability to States to help them optimize their fire protection programs for State and private forest lands.

Pest management now uses a hazard rating system for the occurrence of pest infestations to inform resource managers about the likelihood and risk of forest inventory loss and other damages. This information is used to set stand management priorities and practices. Risk analysis is a regular activity in assessing health risks associated with forest pesticide use and in determining appropriate pesticide use in pest management activities.

Wildfire and pest management are functional activities and largely one-dimensional in terms of risk assessment. Today, national forests are increasingly challenged to address risk assessment and management from a holistic ecosystem management approach that provides for sustaining whole ecosystems in relation to all sources of change and risk. This challenge is extremely complex and burdened with lack of science and data on ecosystem relationships and management interactions. That complexity is further confounded by differences in the views of various interest groups about facts, values and resource management preferences. Today's Panel provides a perspective about how the Forest Service is approaching this formidable ecosystem challenge.

RISK ASSESSMENT IN FOREST RESOURCE POLICY: A POLITICAL PERSPECTIVE

by

John H. Beuter[1]

The idea of risk assessment for forest resource policy has been around a long time. Numerous studies have demonstrated how concepts of decision trees, Bayesian decision analysis, Markov processes, and game theory can be used to estimate maximum expected values for forest resource decisions. Formal risk assessment has been used to choose strategies for wildfire prevention and control, and for determining the value of information and expected values for project-level decisions in reforestation, vegetation control, and the location and design of forest roads.

WHO CARES ABOUT RISK ASSESSMENT?

Despite the appeal of formal risk assessment for forest resource decisions, it is rarely done, and even when it is, it is often ignored. Reasons for avoiding risk analysis include the difficulty of structuring an analysis, lack of easily available data (probabilities, likelihoods, future costs and payoffs), lack of time to do an analysis before a decision has to be made, and, probably most important, a lack of understanding about risk analysis by both policy analysts and decisionmakers. Many natural resource decisions are governed by momentum from earlier decisionmaking which might have been based on rules of thumb, blanket decisions based on averages, and bureaucratic preprogrammed decisions. Fewer are based on problem analysis sensitive to site-specific conditions and the risks associated with alternative paths for transitioning from one state of nature to another.

Reasons for ignoring risk analyses, even when they have been done, include the complication of making decisions conditioned to site-specific information, particularly when such information is lacking and it is uncertain what it is worth to try to get it. Decisionmakers are often risk-averse when risk analysis supports decision responses contrary to those made in the past. Decisionmakers often lack confidence in likelihoods and expected values generated by risk analysis, some are even reluctant to accept the possibility of bad outcomes made visible by risk analysis. Many forest resource managers have lived through cycles of natural, social and economic surprises that invalidated past risk analyses, and having adapted themselves to unexpected circumstances, they tend to have faith in the resilience of nature and the ability of future generations to adapt. They question whether the benefits of formal decision analysis justify its cost in time and dollars.

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[1]Author is Deputy Assistant Secretary for Natural Resources and Environment, U. S. Department of Agriculture. This paper was prepared to present at the annual meeting of the Society For Risk Analysis, December 8-11, 1991, Baltimore Maryland.

Less Need In The Past

In the past, the relative abundance of both forest resources and forest diversity provided a lot of room for error. The mix of public and private forest ownerships, and of land use and forest management practices among various forest ownership classes is the result of land use policies that evolved over the past 200 years in response to entrepreneurship, regional development goals and environmental concerns.

National forests have been subdivided into various categories of reserves, special management areas, and multiple use areas. Land use and management decisions have been generally acceptable as long as they didn't endanger forest sustainability, cause shortages of vital resources, or greatly disrupt social and economic structure. To be sure, controversial actions usually have been accompanied by requisite lobbying and grumbling to affirm interest group positions and power, but in the past there was little need to formally assess risk for either natural ecosystems or human welfare. There was plenty of everything to go around. In an analytical sense, there was plenty of slack.

More Need Today And In The Future

With increasing concern about the sustainability of forest ecosystems and increasing scarcity of forest resources, including nonmarketed resources such as wildlife habitat, it has become more important to be aware of the marginal trade-offs and risks associated with forest resource decisions. There has evolved on the national forests a process of comprehensive forest planning that includes formal analyses to at least implicitly, if not explicitly, assess the environmental risks associated with proposed actions. At minimum, they disclose expected consequences.

Problems faced by today's forest policymakers are characterized by multiple objectives, increasing scarcity, a multiplicity of interests and agendas (including trade-offs between present and future generations), and a lack of patience (or perhaps, a sense of panic). If that weren't enough of a challenge, there is great disparity among national forest stakeholders in their understanding, recognition, or care about commitments associated with past decisions, how past decisions and management actions have contributed to options available today, and the multiple possibilities that exist for achieving desired future outcomes. There is a tendency of advocates working in political and media circles to ascribe deterministic zero-one (all or nothing) outcomes to forest management decisions, e.g., ecosystem preservation or ecosystem destruction, biodiversity or monoculture, species viability or extinction, environmental protection or jobs, log exports or domestic log sufficiency.

There is need for a better understanding of risks associated with alternative courses of action, opportunities for compromises in land use allocations and land management practices, and shared vision for what we mean by multiple use, and the sustainability and availability of forest resources over time.

CASE STUDY: OLD GROWTH, NORTHERN SPOTTED OWLS, TIMBER, AND JOBS

This case study draws heavily on my personal experience and opinion. The focus is national forests in the Pacific Northwest (Oregon and Washington) and northern California. Its purpose is to introduce the complexity of a major forest policy issue and explore opportunities for risk assessment to play a role, even in a politically charged environment.

How We Got Where We Are

At one time virtually all the forests in the nation were in the public domain. Government policies to encourage settlement and development of the frontier transferred vast forested areas to private ownership. The environmental movement of the mid to late 1800s led to creation of the Federal forest reserves to protect watershed and other natural values, and to help provide assurance of sustainable forest resources for the future. Western national forests were carved out of land that had never been subjected to management, other than scattered use by native Americans. Contrary to myth, they were not unbroken expanses of old growth timber, but rather a rich mosaic of wild forest conditions, including a variety of timber age classes resulting from the vicissitudes of nature, including wind, fire, disease, insects, and ecological succession.

In the early 1900s, a general policy of "wise use" management was adopted for the national forests, with emphasis on improving forest access and increasing forest use as a means to enhance development of frontier communities and sustain their social and economic welfare over time. Sustainable timber production and protection of the forest against fire, disease, insects and other natural disturbances were important means to this end. The vision for sustained yield forestry was a "regulated forest" having a balance of age classes, such that the annual growth of the forest could be harvested each year in perpetuity. The rate of old growth harvest was controlled so as to achieve a desired distribution and balance of timber age classes. Nobody thought much about preserving old growth on what was then considered commercial timberland. To the extent such things as biodiversity, ecosystem health, and habitat needs for forest critters were even considered, it was assumed they would be taken care of simply by maintaining a distribution of timber age classes across the landscape.

By the 1970s, progress toward converting national forest timberlands[2] from wild, overmature forests to regulated forests was well underway when researchers began to raise doubts with discoveries about the uniqueness of old growth ecosystems, particularly their importance for certain plant and animal species. While it was true that some old growth

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[2]Only about 39 percent of the forest land on national forests nationwide is currently classified as "suitable timberland." Suitable timberland is capable of economically growing future crops of timber, and is not reserved for other purposes and uses. If used for timber production, it is subject to standards and guidelines to protect associated nontimber resources and environmental values.

forests had already been protected in designated wilderness areas and by management constraints to protect scenery and watershed values, it became apparent that was not likely enough to protect a full representation of old growth ecosystems, and associated plant and animal habitat. Ecologists and others began calling for more old growth protection.

Protection of additional old growth conflicted with sustained yield plans that had envisioned a "nondeclining even-flow" of harvest from the national forests. To maintain the projected sustainable timber harvest schedules, it would be necessary to harvest some old growth well into the 21st century, when harvest could gradually be transitioned to younger regenerated stands as they reached merchantable age classes. The most recent forest plans had already significantly reduced projected sustainable harvest to provide for spotted owl protection and other environmental concerns.[3] No sooner had the forest industry and timber-dependent communities grudgingly acceded to planned harvest reductions, when scientists decided that the spotted owl protection strategy of the forest plans had a low likelihood for protecting the viability of the owl. Instead of the isolated old growth reserves for spotted owls that were provided in the plans, scientists devised a new hypothesis that required more, larger, strategically placed old growth reserves, and significant changes in harvesting practices across the forested landscape.

In the meantime, the northern spotted owl was listed as threatened under the Endangered Species Act (ESA), which set in motion efforts by the U.S. Fish and Wildlife Service to define critical habitat and develop a plan for its recovery for the owl. In March 1991, a court ruling in Seattle Audubon Society v. Robertson enjoined national forest timber sales in owl territory until the Forest Service could document that the viability of the owl was being protected on the national forests. Also during 1991, Congress began wrestling with a number of bills to create an old growth reserve, an effort closely related to spotted owl conservation, but confused by other motives and beliefs. Where might risk assessment fit into this complicated political situation?

The Core of the Problem

Timber harvesting is the core issue in the controversy surrounding spotted owls and old growth. There is little doubt that logging practices in some areas have constituted a threat to the survival of spotted owls. Conversely, there would be little to argue about in proposals to protect the owl, and probably little need for risk assessment, without the precedence of national forest policies to use timber harvesting as a means for fostering forest and community development, and to imply a promise of sustainable harvesting as a

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[3]Some advocates for old growth protection have implied that harvesting plans for the national forests in the Pacific Northwest would result in the extinction of old growth forests shortly after the year 2000. A study by Oregon State University found that national forests in Oregon currently have about 3.0 million acres of old growth, and if they followed their most recent plans for harvest and protection of old growth, they would end up with 2.2 million acres of old growth in the year 2090, *all of it permanently reserved from harvesting* (Sessions et al 1990).

continuing contribution to community stability. Given these precedences, it is arguable that the challenge is to find a way to provide adequate spotted owl protection at minimum cost to timber-dependent communities.

RISK ASSESSMENT AND POLITICAL REALITY

Risk assessment documents the current situation, possible future states of nature or outcomes, and expected values associated with alternative strategies to achieve desired future outcomes. The ESA dictates explicitly that a desired future state is recovery of a listed species from its threatened or endangered status, or alternatively, its recovery from threat of extinction.

The perceived threat of spotted owl extinction arises from loss of suitable habitat for nesting, roosting, foraging and dispersal. Studies show that timber harvesting, particularly clearcutting, and other forest management practices can adversely affect habitat for all these purposes. There is little doubt that some degree of old growth protection can play an important role in spotted owl recovery and survival.

Most remaining old growth stands are on the national forests. If they were all to be preserved to favor the owl, there would be a precipitous reduction of timber harvesting throughout the region, the effects of which would fall most heavily on small, rural, timber-dependent communities, and mostly small timber processors who depend on the national forests for their timber supplies. It has been suggested that harvest reductions on national forests could be offset by increasing harvest from private lands and by reducing log exports, but such possibilities are limited, and even where they exist, it is unlikely that benefit would accrue directly to those most affected by reduced national forest timber harvesting.

A concern about what happens to people, industry and communities introduces considerable complexity to the risk assessment associated with spotted owl recovery. As Marcot and Salwasser (1991) discuss in their paper included in these proceedings, it is hard enough when only the owl is considered and "clean" policy recommendations are made by a consensus of wildlife experts. What happens when you overlay that with economic and social considerations, and the baggage of expectations carried over from past policies?

Limits To Knowledge And The Role Of Advocacy

Gaps in knowledge tend to be bridged with guesses, opinions and folklore. Early studies of spotted owls were concentrated in old growth forests, and the results led some to conclude that owls were totally dependent on old growth. Subsequent studies found spotted owls in a wide variety of stand conditions, leading others to conclude they weren't dependent on old growth. There is enough truth to both positions to give advocates of both old growth preservation and timber harvesting levers to influence policy.

To confuse things further, there are apparent anomalies relative to prevailing theories about owl densities and habitat needs. Owl densities appear to be low on the Olympic Peninsula where the concentration of contiguous old growth forest is greatest, and higher in northern California on intensively managed private land that has virtually no concentrations of classic old growth.

And finally, the ESA requires recovery of the species *throughout its range*. There is no historical record of owl distribution and densities prior to timber harvesting which commenced about 150 years ago. It is assumed the northern spotted owl ranged over lower elevations of the entire forested region west of the Cascade mountains from roughly the Canadian border to Red Bluff, California. With knowledge that, even without timber harvesting, the region is subject to periodic catastrophic fire and wind events that displace suitable owl habitat from place to place, how should "throughout its range" be interpreted?

The most dramatic impact on owl habitat since the turn of the century probably has been clearcut logging, particularly on privately owned forests in northwest Oregon and southwest Washington. Few spotted owls exist in these areas today, and even though part of the owl's historical range, a role for these areas for recovery is questionable. Some biologists believe it necessary to reintroduce enough owl habitat into these areas to support viable populations. Others believe that, even if the habitat was never again suitable for supporting resident owls, there is still a need to provide dispersal habitat connections between the Olympic Peninsula and the Cascade Mountains to reduce the likelihood for genetic isolation that might eventually threaten the viability of owls populations on the Olympic Peninsula. This provides just a taste of the analytical complications of owl recovery, but should make it clear the stakes are substantial.

Ironically, we know more about timber-dependent communities than we do about owls. We can document timber supply vulnerability, economic, social, and cultural risks, and likely impacts resulting from policies that severely and abruptly reduce timber supply. What is lacking is agreement on a desired future state for these communities. The ESA provides the recovery vision as a focus for risk assessment pertaining to the owl. There is no equivalent focus for timber-dependent communities other than what is vaguely provided by the legacy of a past vision of sustained yield forestry and community stability.

Opinion ranges widely about the relevance of timber-dependent communities in the development of a spotted owl recovery plan. Some believe the wood products industry in many locales of the region is doomed anyway because of competition and market trends, and the best that continued old growth harvesting would do is provide a few more years of operation. This view is usually accompanied by faith in the adaptability of people to retrain for new careers, of wood products industries to develop new ventures, and of communities to attract new industries and diversify their economic base.

An opposite view holds that the forest products industry will remain a vital part of the economy of the region, in fact, that the economic welfare of the region may depend on it. Rather than just sustaining timber-dependent areas for a few more years, old growth

harvesting is needed to maintain infrastructure investment and work force until second growth timber from private and public lands reaches commercial size over the next 20 years. This view is often accompanied by faith in the adaptability of forest management practices to provide suitable owl habitat, and for timber harvesting and owls to coexist with enlightened forest management. It is believed that the social and economic costs associated with severe reductions in timber supply are unacceptable and avoidable.

Balancing The Risks

The northern spotted owl was listed as a threatened species list because its status evaluation concluded that forest management trends (mainly clearcutting) are endangering future survivability. Since the listing in 1990, many more owls have been discovered than were believed to exist at the time of listing, many of them in managed forests. Existing owls are being protected, and much more owl habitat is being protected and enhanced on both public and private lands throughout the region. It seems less likely today that the owl is threatened with extinction than might have been thought only a year or two ago. Conversely, it seems more likely today than it did a few years ago that forest management can be made to be more compatible with owl conservation. Yet, polarized views of owls vs. timber still dominate public, political, and even some scientific perception of the issue.

It seems apparent that some sort of comprehensive risk analysis would be useful for finding a balanced solution to owl protection. In the absence of information about risk, it is almost certain public sentiment will favor more, rather than less, owl protection. Thus, it is a political reality that there is little incentive for advocates of old growth and owl protection to support comprehensive risk analysis because of the chance it might result in less protection than might be selected without such analysis.

The issue is not simply how much old growth protection is needed, but it also includes consideration of forest management alternatives, both inside and outside of old growth reserves. Should forest fires be controlled? Should salvage of dead timber be allowed? Should roads and trails be allowed in reserve areas? Could thinning and selective harvesting occur without significant threat to the owl? The easy answer is to avoid any chance of adversely affecting owls by not allowing forest management activities inside reserve areas, and even limiting them outside.

But what if forest management activities could provide significant economic and social benefit with negligible adverse impact to owls, or perhaps even be used to enhance owl habitat? Some argue that would just introduce another type of risk: the chance for unintended bad outcomes to result from well-intentioned management activities. Can you trust forest managers and woods workers to do the right thing? If you believe not, there seems to be no reason to support management activities, or any risk analysis that might justify them.

A balancing of risks would require site-specific analysis of communities and local economic areas to document vulnerability (risk) of significant social and economic disruption. This information could then be used to seek opportunities for avoiding or mitigating undesirable economic and social consequences in the formation of owl recovery alternatives. For example, suppose an old growth preservation alternative provides a 95% likelihood of owl recovery, but would virtually eliminate national forest timber harvesting in a timber-dependent locality. Suppose further that there is a 95% likelihood that the loss of timber supply would cause a mill employing 200 people to go out of business, affecting directly the lives of an additional 400 family members of displaced forest products workers, and indirectly, other employment supporting another 800 other people in the community. Other economic costs would include a likely reduction in property values, losses of property and income tax revenue, as well as payments in lieu of taxes foregone because timber harvesting is curtailed on the national forest. It is likely there will be social costs caused by frustration, stress, and loss of self-esteem, while at the same time, losses of taxes and in-lieu payments will decrease the availability of social services. All in all, this adds up to a high likelihood for significant social and economic disruption.

Now, what if there was a recovery alternative that reduced the likelihood of significant social and economic disruption from high to moderate, while only reducing the likelihood of owl recovery from 95% to 90%? In other words, an alternative that would provide enough timber to keep the mill running, even if at reduced output, until other sources of timber came on the market. Would it be worth a slight marginal increase in risk to the owl to significantly reduce the risk of serious social and economic disruption? This is clearly a valid political question, but it can't be answered with much confidence without some analysis showing the opportunities to balance the risks. In fact, the question probably wouldn't even get asked unless some such analysis gave evidence that it could be resolved.

Timing Of Risk Analysis

In the public policy arena, timing is everything. Good ideas at the wrong time may have less chance for serious consideration than marginal ideas at the right time. From the spotted owl example, it can be hypothesized that the best time to do risk analysis would be in conjunction with the ESA listing decision analysis. Indeed, listing decisions are statements of perceived risk to the survival of the species under an existing undesirable condition, often related to human activity. Typically, listing decisions involve a narrow consideration of the biological risk to a species, assuming the undesirable human activity will persist unless curtailed by government action. There are no requirements to portray the biological risk in a more comprehensive framework of possibilities for mitigating or eliminating the undesirable conditions and reducing the risk to the species. The perception of high risk to a species inherent in a listing decision may be conditioned by limited perceptions of the options that exist for mitigating undesirable conditions and the willingness of people to cooperate to solve the problem.

From a public policy standpoint, a narrowly conceived listing decision and the legal requirement for species recovery (implicitly, at any cost) is almost certain to put the weight of public opinion and political momentum on the side of urgent government action to favor the species. Without judging the extent to which that might be warranted, that perception will tend to make it harder to achieve a balanced assessment of likelihoods and expected values for a range of recovery alternatives. Special interests are likely to resist any comprehensive risk assessment that is not likely to serve their interests. As case in point, some have questioned whether social and economic consequences are relevant to the listing actions and recovery planning under the ESA.

It would seem desirable for a listing decision analysis to include an assessment to balance the risk to the species against the expected values of mitigation alternatives.[4] This may be controversial because it would require interdisciplinary, rather than only wildlife specialist, participation in listing decision analyses, but it would likely enhance public understanding of the situation, and foster a more balanced approach to public policy formation. At minimum, it would give the recovery team a place to start. Even if it weren't done in the prelisting analysis, it should be considered as a required first step of the recovery planning process.

SUMMARY AND CONCLUSIONS

Formal risk analysis has been used in a variety of forest resource decision applications, mostly at the project level. It is considered, at least implicitly, in strategic forest planning in the documentation of expected consequences of land and resource management decisions over the planning period.

As forest resources become less abundant in the face of increasing knowledge and concern about environmental risks, comprehensive analysis to seek a balance of risks becomes ever more important. Nowhere is this more evident than in the interaction between the requirements of the Endangered Species Act and other legal mandates for multiple use forest management on the national forests.

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[4]The Interagency Scientific Committee conservation strategy for the northern spotted owl (Thomas et al 1990) is an example of a prelisting analysis, but it was done separately from the listing decision analysis. It was accomplished by wildlife biologists focusing primarily on the risks to the owl. There was a cursory consideration of social and economic impacts, with no input from other disciplines nor any attempt to balance biological and social and economic risks.

The so-called "Gang of Four" scientists (Johnson et al 1991) did an interdisciplinary assessment of risk, but this analysis was done in the political arena at the request of two subcommittees of the U.S. House of Representatives. The analysis focused mainly on the risk to the spotted owl and other old growth related species. It considered several forest management alternatives, but didn't address social and economic risks to timber dependent communities. That is, although they used foregone harvest and employment as a measure of the cost of their alternatives to reduce risk to old growth related species, they did not consider alternatives to balance social and economic risks against the species' risks.

The chances for accomplishing comprehensive risk assessment in the public policy arena may diminish once public opinion has been captured by special interests. As long as advocates can use uncertainty and a lack of knowledge to cast issues as deterministic zero-one choices, it is to their benefit to forestall attempts to balance risks. Without public perception that comprehensive risk assessment can lead to decisions that increase public benefit, it is unlikely it will be supported or taken seriously. The challenge is to demonstrate that risk assessment has an important role to play in public policy analysis. There are many opportunities to do so, and perhaps none so ripe in forest resource policy as the need to balance risks between the protection of ecosystems, plants and animals against those related to the social and economic welfare of the human species. That sounds a lot like politics!

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VIEWS ON RISK ANALYSIS FOR WILDLIFE PLANNING AND MANAGEMENT IN USDA FOREST SERVICE

by

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ABSTRACT

Risk analysis and management are being explored in the planning and managing of wildlife species and habitats on national forests. Direction for conducting such assessments comes from the Council on Environmental Quality and from current scientific theory that views viability of wildlife populations as likelihoods of continued existence. The National Forest Management Act of 1976 and pursuant regulations set general guidelines for maintaining diversity of plant and animal communities and population viability of native and desired nonnative vertebrate species on national forests. Assessing risk to viability of wildlife populations is done in Environmental Impact Statements under the National Environmental Policy Act of 1969.

The EIS discloses the risk assessment, scientific uncertainties, and estimates of risk to population viability under alternative management schemes. Risks are weighed by decision-makers in selecting a management alternative that fits their risk attitudes and that meets overall resource management goals for the area in question. Selecting a management alternative initiates risk management, which sets goals for kinds, amounts, and distributions of wildlife populations and habitats. Criteria used to select a course of action often include unwritten political and managerial constraints.

WILDLIFE PLANNING AND MANAGEMENT IN USDA FOREST SERVICE

Decision analysis and risk evaluation have been used in a variety of cases to help plan for wildlife conservation (Maguire 1986, 1991, Marcot 1986, Millsap et al. 1990, Nnaji et al. 1983, Thompson 1991). In this section we review the legal and administrative mandates for managing wildlife resources on national forests and for evaluating risk of management activities.

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Mandates for Wildlife Planning and Management

The USDA Forest Service is required to manage habitats to maintain viable populations of wildlife species, and for diversity of plant and animal communities on national forests and national grasslands, under fiat of the National Forest Management Act (NFMA) of 1976 and its pursuant regulations (36 CFR 219). Specifically, the Regulations for National Forest System Land and Resource Management Planning establish the goal that "Fish and wildlife habitat shall be managed to maintain viable populations of existing native and desired nonnative vertebrate species in the planning area" (36 CFR 219.19). Further, the regulations stipulate that "All management prescriptions shall ... provide for adequate fish and wildlife habitat to maintain viable populations of existing native vertebrate species (36 CFR 219.27(a)(6)).

These legal mandates set the stage for considering population persistence in a risk assessment framework. In providing for viability of wildlife populations, a working definition of population viability as been devised (Marcot et al. 1986):

> A viable population is one whose likelihood of continued existence in a planning area for a specified time is judged by responsible individuals to meet the requirements of law and regulations pursuant to the maintenance of biological diversity.

Likelihoods of continued existence for wildlife populations can be estimated through analysis of the relationships between wildlife population size, population trend, and how management of the species' environment would trigger events that might change the amount and distribution of habitats and available resources (Fig. 1). Such analyses began to be framed as risk assessments in the early 1980's (Salwasser et al. 1984) following a seminal paper by Shaffer (1981). In this approach, likelihoods of continued existence are estimated as probabilities that specific environmental, demographic, and genetic factors would provide for persistence of a wildlife population within a planning area (e.g., National Forest or Region) for a specified period of time (e.g., 100 years). The estimated likelihoods are also based on interpretations of scientific uncertainty (Shaffer 1987) in the gauging of parameters or in the understanding of basic population attributes (Marcot and Holthausen 1987).

Assessment of risk in providing for diversity of plant and animal communities has only recently begun to follow the same framework as for population viability. In both cases, conservation goals can be expressed as probabilities of persistence given existing knowledge and ramifications of uncertain scientific information.

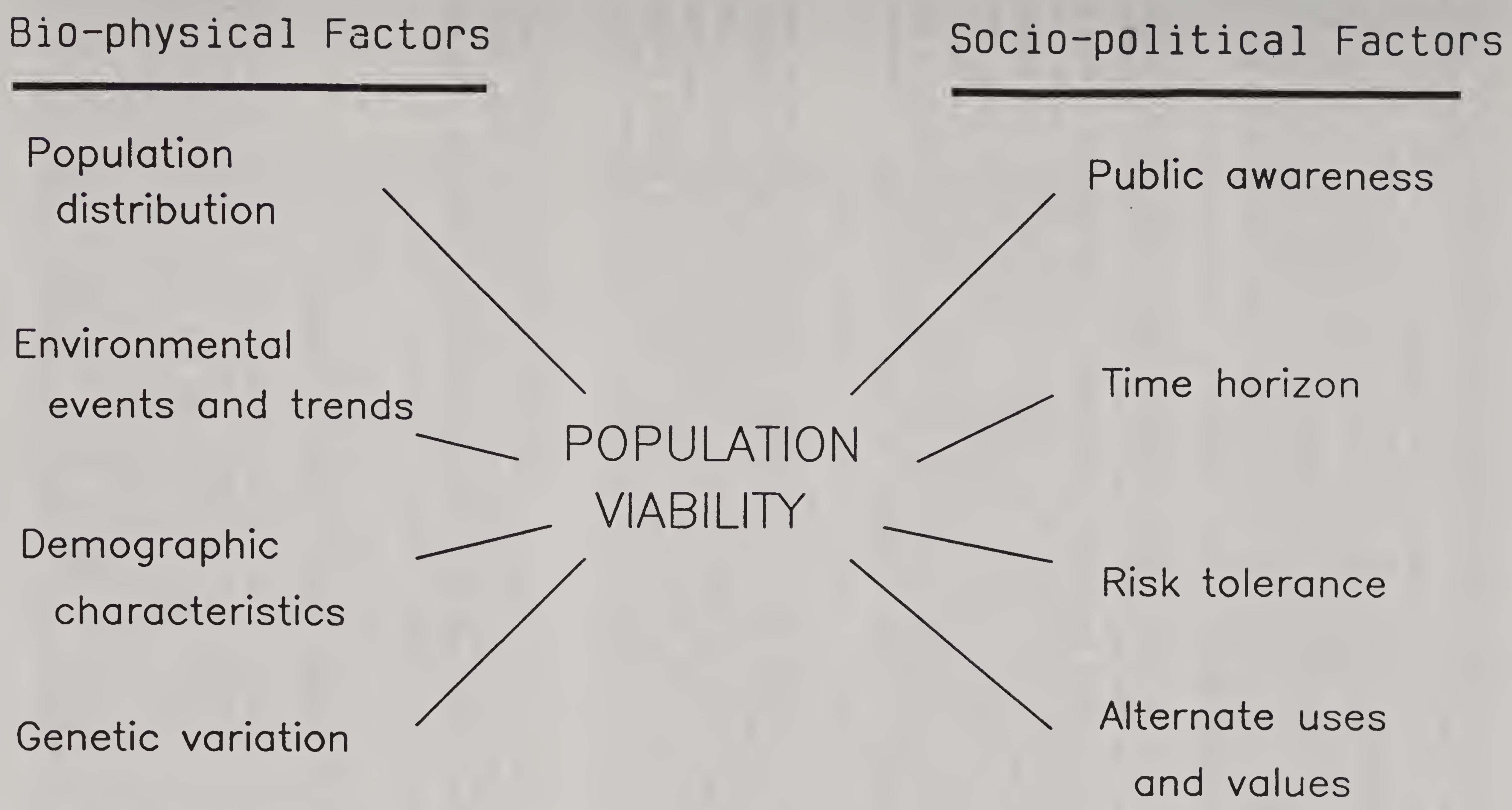

Figure 1. Bio–physical and socio–political factors that influence wildlife population viability, and that are considered in a viability risk assessment.

Whether the goal is population viability or biodiversity, specific environmental factors affect probabilities of persistence (Shaffer 1981, 1990). Examples include the effects of modifying habitat conditions, such as urban development in the foraging range of the California condor (Gymogyps californianus) which has eliminated sources of carrion, the bird's principle diet; and invasion by disease organisms to an imperiled population, as in the case of canine distemper in black-footed ferrets (Mustela nigripes) brought into captivity for breeding. A positive example is the lessening of risk provided to hawks, eagles, and falcons from reducing toxins from their food chains. This last example also illustrates the use of viability risk analysis in ecotoxicology (Marcot, in press).

In most wildlife viability risk assessments to date, risk factors have been qualitatively ranked from low to high risk based on how well each possible management alternative performs. Such ranking of likelihoods is made as ordinal-scale categories rather than quantified as ratio-scale probabilities because we do not yet understand how multiple environmental risk factors compound, for example how habitat loss, habitat fragmentation, and habitat productivity declines would interact on dependent species. Ordinal scale rankings have been used in EIS and analysis documents to evaluate efficacy of management plans for the northern spotted owl (Strix occidentalis caurina) (USDA 1988a, 1991) (see Tables 1 and 2) and for conserving old-growth forest ecosystems in the Pacific Northwest (Johnson et al. 1991) (see Table 3).

In a few cases, especially for wildlife species with restricted distributions, risk factors have been quantified. Examples include the decision analyses for conserving the threatened Concho water snake (Natrix harteri paucimaculata) in Texas (Soule 1989), allocating scarce zoo space for conservation of tigers (Panthera tigris) (Maguire and Lacy 1990), conserving grizzly bears in the wild (Ursus arctos) (Maguire 1986), and managing habitat for the threatened Stephen's kangaroo rat (Dipodomys stephensi) in southern California (Burke et al. 1991).

A subsequent step in the process of planning for viable wildlife populations on public lands calls for decision-makers (line officers) to determine and explain acceptable levels of risk for simultaneously meeting wildlife and other resource management objectives. This step entails risk management and is discussed below.

Legal Regulations on Environmental Assessments and Uncertainty

Analysis of the estimated environmental consequences of management activities on national forests is required under the National Environmental Policy Act of 1969 (NEPA) (14 U.S.C. Sec. 4321, et seq. [1970]). The NEPA requires full examination of past and potential effects of management activities, the degree of uncertainty in our technical knowledge, and levels of risk in forest management decisions. NEPA mandates such disclosure in Environmental Impact Statements. In this framework, NEPA provides a holistic approach that acknowledges uncertain knowledge and decision risks. The USDA

Forest Service follows NEPA guidelines in writing EIS's, including those dealing with wildlife planning.

Analysts face a timeless dilemma. How should less than perfect scientific information on wildlife species and their habitats be handled in NEPA assessments? The Council on Environmental Quality (CEQ) published (51 FR 15618, April 25, 1986) a regulation on dealing with incomplete or unavailable information when preparing an environmental impact statement. It directs agencies to obtain essential information for including in the EIS, if costs are permissible, or to include a statement about the incomplete or unavailable information that meets certain specified requirements. The regulation also provides guidance on how to deal with scientific uncertainty:

> If the agency is unable to obtain the information because overall costs are exorbitant or because the means to obtain it are not known, the agency must (1) affirmatively disclose the fact that such information is unavailable; (2) explain the relevance of the unavailable information; (3) summarize the existing credible scientific evidence which is relevant to the agency's evaluation of significant adverse impacts on the human environment; and (4) evaluate the impacts based upon theoretical approaches or research methods generally accepted in the scientific community. ... Impacts which have a low probability of occurrence but catastrophic consequences if they do occur, should be evaluated if the analysis is supported by credible scientific evidence and is not based on pure conjecture, and is within the rule of reason (Federal Register 1986:15620).

CEQ advanced this regulation because

> it has concluded that the new requirements provide a wiser and more manageable approach to the evaluation of reasonably foreseeable significant adverse impacts in the face of incomplete or unavailable information in an EIS. The new procedure for analyzing such impacts in the face of incomplete or unavailable information will better inform the decision-maker and the public (Federal Register 1986:15620).

The CEQ regulation calls for disclosing when vital information is incomplete or unavailable. It also calls for using the best available information, methods, and theoretical approach to estimating impacts. The overall intent of the regulation is to provide decision-makers and publics with the best available professional assessments on potential or likely impacts. It also provides for recognizing uncertainty in scientific information so that risks can be more clearly understood and accounted for in public opinions and in the decision-making process.

Table 1. Rule set for estimating probability of persistence of a population, as used with the viability assessment of northern spotted owls in Oregon and Washington (USDA 1988a).

	DEMOGRAPHIC AND GENETIC STABILITY		HABITAT SIZE	HABITAT DISTRIBUTION
Probab. level[a]	Demographic effect (prob. of N > min)[b]	Genetic effect (inbreed. coeffic.)	HSI value[c]	Nearest-neighbor distances (mi)[d]
VERY HIGH	>0.95	≤0.05	>0.95	<2
HIGH	0.80-0.95	0.06-0.20	0.80-0.95	2-6
MODERATE	0.60-0.79	0.21-0.35	0.60-0.79	7-15
LOW	0.40-0.59	0.36-0.50	0.40-0.59	16-21
VERY LOW	<0.40	>0.50	<0.40	>21

[a]Probabilities of persistence classes are defined as follows:

VERY HIGH: Continued existence of a well-distributed population on the planning area at the future date is virtually assured. This is likely even if major catastrophic events occur within the population, research finds that the species is less flexible in its habitat relationships, or if demographic or genetic factors are more significant than assumed in this analysis.

HIGH: There is a high likelihood of continued existence of a well-distributed population in the planning area. There is limited latitude for catastrophic events affecting the population or for biological findings that the population is more susceptible to demographic or genetic factors than was assumed in the analysis.

MODERATE: There is moderate likelihood of continued existence of a well-distributed population in the planning area at the future date. There is no latitude for catastrophic events affecting the population or for biological findings that the population is more susceptible to demographic, genetic, or habitat distribution factors than was assumed in the analysis.

LOW: There is a low likelihood of continued existence of a well-distributed population in the planning area at the future date. Catastrophic, demographic, genetic, or habitat distribution factors are likely to cause elimination of the species from parts or all of its geographic range during the period assessed.

VERY LOW: There is a very low likelihood of continued existence of a well-distributed population in the planning area. Catastrophic, demographic, or genetic factors are highly likely to cause elimination of the species from parts or all of its geographic range during the period assessed.

[b]Probability that a population, with stochastic birth and death rates, will exceed a population size representing a well-distributed population, within a specified period of time. These probabilities were

estimated as the proportion of stochastic Leslie-matrix life table runs using fluctuating reproductive and juvenile survival rates that remained above specific population levels. Well-distributed population sizes were defined for each population modeled as the theoretical density that would result from a distribution of breeding pairs spaced no further apart than the median dispersal distance of juveniles (23 miles).

[c]Habitat Suitability Index values are the probability that a designated spotted owl habitat area of given amount would actually support a breeding pair. (See USDA Forest Service 1988a for model used for quantifying this relationship.)

[d]Habitat distribution as compared to dispersal distances of juvenile spotted owls. (See USDA Forest Service 1988a.)

Table 2. Examples of describing 4 management alternatives for providing spotted owl habitat on USDA Forest Service lands in the Pacific Northwest, showing probabilities of persistence afforded to each population, as used with the viability assessment of northern spotted owls in Oregon and Washington (USDA 1988a).

	Probability of persistence[a] to year:				
Description of alternative	Area	15	50	100	150
1. DO NOT SPECIFICALLY MANAGE FOR SPOTTED OWL HABITAT -- habitat would therefore be provided by default in wilderness or other reserved areas.	OLPE[b] WACA ORCA CORA	M M VH [c]	L L M M	VL L L L	VL VL L L
2. PROVIDE A NETWORK DISTRIBUTION OF HABITAT AREAS RANGING FROM 1000 TO 2700 ACRES OF SUITABLE HABITAT FOR EACH AREA	OLPE WACA ORCA	M M VH	M M H	M L M	L L L
3. MAINTAIN ALL CURRENTLY SUITABLE HABITAT -- no additional harvesting or reduction of habitat would be allowed on National Forest lands.	OLPE WACA ORCA	H H VH	H H H	M M H	M M H

[a]Probability of persistence as defined in Table 1. VH = very high, H = high, M = moderate, L = low, VL = very low.

[b]Levels of protection are shown for each population, denoted by Physiographic Provinces: OLPE = Olympic Penninsula, WACA = Washington Cascades, ORCA = Oregon Cascades and Klamath Mountains, CORA = Oregon Coast Range. CORA is isolated only under Alternative 1 and is part of the ORCA population under Alternatives 2 and 3.

[c]Oregon Coast Range not isolated at this time period.

Table 3. A risk-ranking scale used by Johnson et al. (1991) to evaluate the probabilities of persistence of functional late successional forest ecosystems, northern spotted owl populations, marbled murrelet populations, other late successional forest wildlife species, and sensitive fish stocks, on federal lands in the Pacific Northwest U.S. The scale was used to rank effects of 14 management alternatives and was applied by using best professional estimation of effects in a consensus meeting of ecologists and wildlife biologists.

VERY HIGH (VERY RELIABLE) - Denotes a very high likelihood (reliability) of providing habitats and environmental conditions for conserving well-distributed, ecologically functional late successional forests and their associated species, on the order of a century or longer. Provides broadest available latitude for natural catastrophes and uncertainties in our knowledge.

HIGH (RELIABLE) - Denotes a high likelihood (reliability) of providing habitats and environmental conditions for conserving well-distributed, ecologically functional late successional forests and their associated species, on the order of a century or longer. Provides some latitude for natural catastrophes and uncertainties in our knowledge.

MODERATE-HIGH (SOMEWHAT RELIABLE) - Denotes a moderately high likelihood (reliability) of providing habitats and environmental conditions for conserving well-distributed, ecologically functional late successional forests and their associated species, on the order of a century or longer. Provides limited latitude for natural catastrophes and uncertainties in our knowledge.

MODERATE (UNCERTAIN) - Denotes a roughly 50/50 likelihood (reliability) of providing habitats and environmental conditions for conserving well-distributed, ecologically functional late successional forests and their associated species, on the order of a century or longer. Provides no latitude for natural catastrophes and uncertainties in our knowledge.

LOW-MODERATE (SOMEWHAT HARMFUL) - Denotes an unlikely (less than 50/50) chance of providing habitats and environmental conditions for conserving well-distributed, ecologically functional late successional forests and their associated species, on the order of a century or longer. Provides no latitude for natural catastrophes and uncertainties in our knowledge.

LOW (HARMFUL) - Denotes a highly unlikely (much less than 50/50) chance of providing habitats and environmental conditions for conserving well-distributed, ecologically functional late successional forests and their associated species, on the order of a century or longer. Provides no latitude for natural catastrophes and uncertainties in our knowledge. Local extirpation of late successional species or habitats from natural catastrophes and uncertainties in our knowledge is very probable.

VERY LOW (VERY HARMFUL) - Denotes a very highly unlikely (very much less than 50/50) chance of providing habitats and environmental conditions for conserving well-distributed, ecologically functional late successional forests and their associated species, on the order of a century or longer. Provides no latitude for natural catastrophes and uncertainties in our knowledge. Local extirpation of late successional species or habitats from natural catastrophes and uncertainties in our knowledge is very probable. Local or regional extirpation of late successional species or habitats from natural catastrophes and uncertainties in our knowledge is highly likely.

Implications of this regulation are pertinent to wildlife analyses when data on population or habitat trends as well as basic ecological information on species are lacking or incomplete and will likely remain so for the foreseeable future. Where feasible, applying ecological theory to estimating population trends and habitat relationships might be appropriate. But data-free analysis is a poor substitute for empirical field data when high social or economic costs are involved.

The USDA Forest Service has tested the CEQ regulation for risk assessment in a number of wildlife cases. We have found that predicting likelihoods of viability for wildlife populations beyond just a few years is complicated by incomplete habitat inventories and current population censuses, and by the inability to precisely predict future stochastic events such as droughts, insect epidemics, and forest stand-replacing wildfires. Such uncertainties result in increasingly wide confidence intervals in predicted levels of security for more distant future dates.

An example is the population viability analysis conducted on the threatened Mt. Graham red squirrel (Tamiasciurus hudsonicus grahamensis). The analysis highlighted the lack of information on future food abundance; explained the need for such information; synthesized current scientific knowledge; and projected impacts on the squirrel population by use of stochastic population modeling. The analysis also called for additional study of how development activities on Mt. Graham could further imperil the squirrel (USDA 1988b). The risk of catastrophic loss of the population from ongoing development activities was assessed by using stochastic demographic modeling and best professional judgment. Whether the evaluations are "within the rule of reason," as the CEQ regulations require, might be for the courts to decide, as appeals and litigation on the case continue as of this writing.

Categories of Uncertainty in a Wildlife Analysis

Wildlife risk assessments have disclosed two major classes of uncertainty (Marcot 1986): scientific uncertainties and decision-making uncertainties. Scientific uncertainties arise because (1) the system itself is poorly understood and is inherently variable and difficult to predict, (2) the process of estimating the variables of interest is imperfect, (3) the models used to generate predictions or estimations are always in some sense imperfect, or (4) the scientific question being asked may be ambiguous or incorrect. Decision-making uncertainties arise when (1) the risk attitude of the decision-maker or public changes over time, (2) the perceived utility (economic or social value) of a decision changes over time, is unknown, or cannot be quantified in units commensurate with opportunity costs (e.g., the amenity value of an old-growth forest as compared with the dollar value of harvested timber), and (3) the political or administrative environment does not provide for a decision space that would satisfy all key constituents, i.e., goals for conserving a rare species such as the northern spotted owl and goals for providing a valued resource such as timber are directly incompatible. In the face of any of these factors, decisions made rationally might

still lead to undesirable outcomes, such as increased risk of species extinction, excessive social and economic disruption, or judicial intrusion into technical and scientific matters.

RISK ASSESSMENT AND RISK MANAGEMENT

Environmental impact statements bridge the gap between risk assessment and risk management. In the case of providing for viable wildlife populations on national forests, the Forest Service conducts risk assessments as part of the EIS process, whereafter agency decision-makers select and institute a course of action. These decisions must by law (NFMA and the Multiple-Use Sustained Yield Act of 1960) also address multiple resource goals and the potential cumulative effects of activities over time and across administrative boundaries.

Risk assessments of population viability or biological diversity are the easy part. They are more or less tractable to statistical methods of assessing reasonably certain trends such as habitat change, stochastic events such as fires and epidemics, and uncertain information such as the effect of habitat fragmentation on vagile species. What is becoming increasingly obvious is that risk management is the ultimate goal and it is harder to conduct than risk assessment.

In decision-making it is important to ask, what is uncertain and what is at risk? Those involved in biologically-based risk analyses of wildlife population viability have assumed that decision-makers would view environmental impacts on species existence as the central risk factor. However, in real-world circumstances of conflicting social values, economics, and politics what is at risk might be the loss of future political decision space, favor among supervisors, or even one's job.

Many factors determine the decision space when planning for viable wildlife populations or more generally biological diversity on national forests. Such factors always include the political, social, and economic setting and the administrative context. These are at least equal in importance to the technical facts of a biological risk assessment in final decisions on a multifaceted public policy. In a democratic society, these are appropriate components of balancing the many values and uses of multiple resources on public lands. However, risk assessment alone cannot solve intractable conflicts that are internal to agency policies or external among special interest groups and publics with diametrically opposed interests. New approaches to conflict resolution are needed to address this facet of risk management (e.g., Maguire, this volume).

PROBLEMS AND OPPORTUNITIES

There are a number of problems that risk assessment for wildlife has to confront. These include the continual need for better inventory data and basic life history information on species and their ecosystems, and education of professional wildlife biologists in risk

assessment theory, methods, and applications. Risk management also needs a more formal process for adaptive management (Holling 1984), including expanded funding and execution of monitoring programs, and developing technical and administrative criteria for reevaluating management direction based on the results of the monitoring studies.

The mandates for multiple-use management of national forests (NFMA, MUSY) create an inherent conflict in resolving issues of balance between competing resource values and uses such as risk levels to rare wildlife and production of desired resources from the habitats of those species. Wilkinson and Anderson (1987:373) noted that "the result [of NFMA] is an uneasy marriage of science, economics, history, public administration, abstract values, and the rule of law." Conflicts arise because different segments of the public, and even different staff specialists and decision-makers in the responsible agency, champion different resources on the same public lands, and the lands cannot support everyone's interests to the same degree. Such conflicts manifest themselves in wildlife risk assessments as such questions as: What level of certainty should management plans provide in insuring wildlife population viability or biological diversity, if opportunity values of alternative uses of the land are high? Over what time period (e.g., years, decades, centuries, or millennia) should viability and biological diversity be provided with a specific level of certainty?

These questions were raised early in the application of risk assessment to wildlife (Shaffer 1981, Salwasser et al. 1984). A number of recent case studies have shown that they still need to be resolved to the satisfaction of biologists, decision-makers, and publics. Cases such as conserving northern spotted owls in ancient conifer forests of the Pacific northwest, red-cockaded woodpeckers (Picoides borealis) in old-growth longleaf pine forests in the southeast, and northern goshawks (Accipiter gentilis) in mixed conifer forests of the southwest all make this unresolved need obvious. In each case there is a high opportunity value of alternative uses of the land, and a vocal, active constituency for both the wildlife species and the alternative land uses.

Litigation on policy decisions that have used risk analysis to evaluate effects of management activities on wildlife populations generally have focused on attacking the procedures, particularly the models (Marcot and Thomas, in prep.), instead of the content of the decision and the degree to which it reached a prudent balance between conflicting goals (see Kohm 1991, Wilkinson and Anderson 1987). These could doom risk assessment as a socially viable decision-making tool.

On the positive side, a risk assessment coupled with explicit decisions for risk management provides opportunities to:

- differentiate the roles of technical specialists and decision-makers,
- keep the role of science in resource evaluations relatively "clean" from special interests and political sway,
- engage outside specialists as peer reviewers and cooperators in the technical parts of environmental impact assessments,

- clarify the technical, political, and economic bases for resource management decisions, and
- encourage public comment and participation on draft evaluations and pending resource management actions.

CONCLUSION

The main alternative to explicit risk assessment and risk management in wildlife policy making is decisions by consensus of experts. It is the traditional approach and may continue under current laws and regulations. It is "clean" in that it absolves decision makers and elected officials from the need to make hard choices; they need only accept and hide behind the choice of the experts. Unfortunately, the world is closing in on natural resources and we have already reached the point where we either must consciously make less than ideal choices with better knowledge of options and likely consequences, i.e., risk assessment and management, or quickly find out which experts trump all the others. Recent cases under the Endangered Species Act make the answers to the latter question fairly clear. The ultimate utility of risk assessment in wildlife applications is yet to be determined.

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DECISION ANALYSIS AND ENVIRONMENTAL DISPUTE RESOLUTION: PARTNERS IN RESOLVING RESOURCE MANAGEMENT CONFLICTS

by

Lynn A. Maguire[1]

The United States Forest Service has a strong history of scientifically based, professional land management. Over the past 20 years, this tradition has been overlain by legislation and regulations mandating a broader range of concerns for forest management and increasing public input to forest management decisions (Fig. 1).

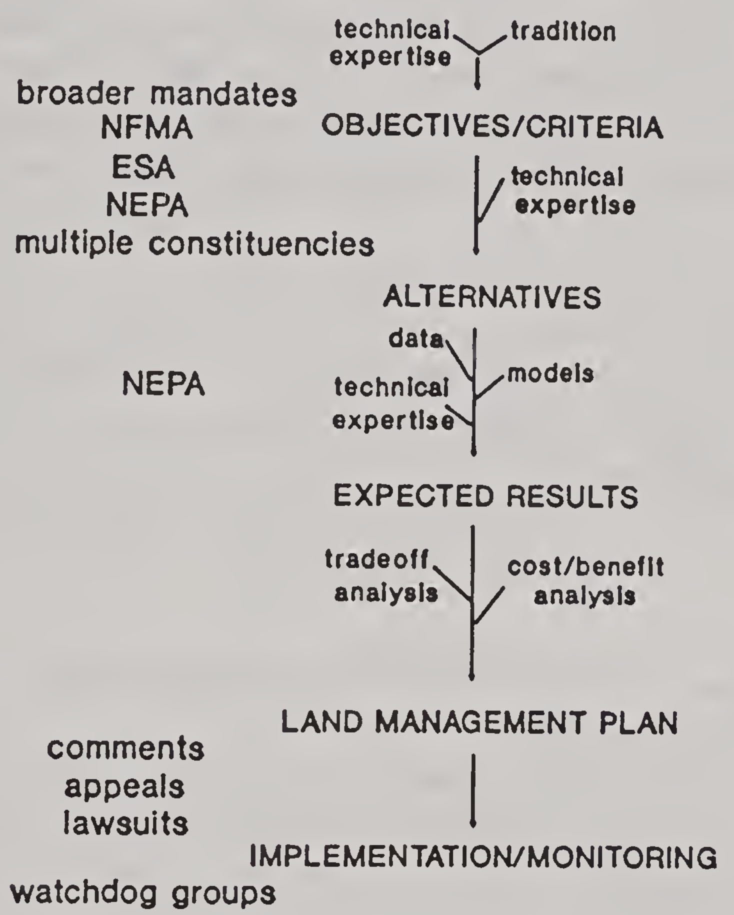

Fig. 1. Schematic Flowchart of National Forest Planning

Forest planning under the National Forest Management Act and the National Environmental Policy Act has been characterized by an uneasy merger of technical analysis, including linear programming models such as FORPLAN, and public participation, expressed through meetings, comments on draft plans, appeals and litigation. This process has been unsatisfactory, both because it often fails to satisfy the interests of forest user groups and because unresolved protests from these groups can virtually paralyze forest

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management activities (Wondolleck 1988). What is needed is a way to make public participation and scientific analysis work in concert to produce land management plans that do the best job possible of meeting conflicting human needs and protecting the environment. Research is underway to develop such a framework by combining the elements of decision making under uncertainty with those of environmental dispute resolution. The purpose of this paper is to outline this framework and describe the initial phases of its application to a forest planning effort on the Chattahoochee National Forest in northern Georgia.

METHODS

Decision Analysis

The two main components of decision making under uncertainty are the "probability" model and the "utility" model (Raiffa 1968, Behn and Vaupel 1982). The probability model is a description of how the decision maker thinks the world works: what features link actions taken to results achieved, what uncertain events in the natural or sociopolitical environment can affect those results, and how likely those events are (Fig. 2).

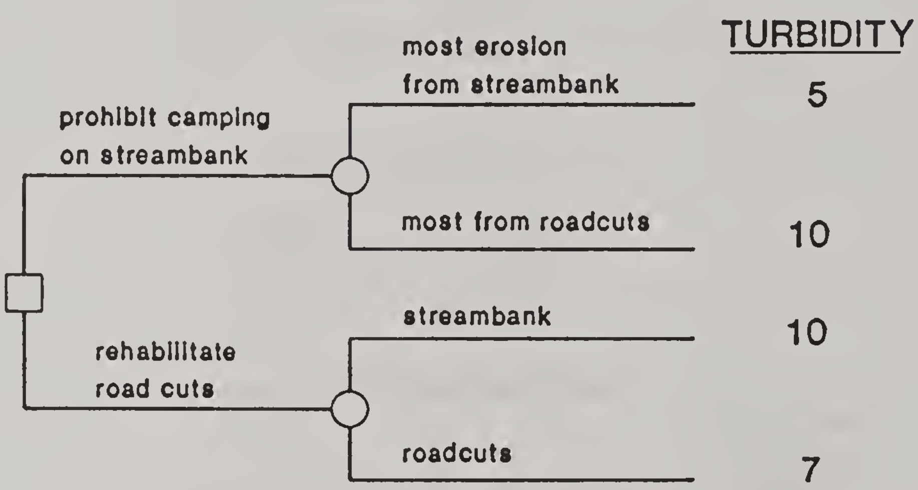

Fig. 2. Decision Tree Showing Alternative Actions, Random Events and Outcomes

The utility model is a description of how the decision maker values possible results. It includes a statement of objectives indicating what is valued, specific criteria for measuring how well different actions might meet the objectives, utility functions for describing relative preferences among a range of criteria values, and multiattribute utility analysis or tradeoff analysis to weigh conflicting objectives. These features will be described in more detail using the forest planning example.

Decision analysis links the probability and utility models by proposing that the best action under uncertainty is the one with the best expectation of success. That action is determined by using the probabilities of uncertain events to weight the values assigned to different outcomes and choosing the alternative with the highest expected utility (see Maguire 1986 for example of calculations applied to endangered species management). Additional analyses can then be made to determine whether the choice of alternative is easily changed by adjustments in the probability or utility models, to analyze the value of gathering additional information to reduce uncertainty, or to assess tradeoffs among conflicting objectives.

Environmental Dispute Resolution

Environmental dispute resolution is an application of principled negotiation (Fisher and Ury 1981) to environmental issues. Some of the main features of dispute resolution techniques are: (1) The focus is on the interests, or underlying objectives, of the parties to the dispute, rather than on their positions, or demands for action. (2) The parties are encouraged to engage in joint fact-finding, sharing information, assumptions, models, analyses and results. (3) The parties, perhaps with the help of an intervenor, attempt to find solutions that provide joint gains, rather than solutions where one party's gain must come from another's loss. (4) These opportunities for joint gain are created by taking advantage of differences among the parties in interests, priorities among interests, risk preferences, time preferences, and capabilities. (5) The parties appeal to jointly accepted objective standards for apportioning gains. And, (6) the aims of the process are a consensus on action, successful implementation of the action selected, and an improvement in future working relationships among the parties.

Combining Decision Analysis and Dispute Resolution

Decision analysis can assist in dispute resolution by providing a framework for each party to display its views of the facts involved in a dispute (using the probability model) and its interests and preferences (using the utility model). Explicitly displaying both facts and values helps the parties, and any intervenors, to understand the sources of disagreement leading the parties to advocate different actions. Appealing to maximum expected utility as a decision rule provides a jointly accepted standard for choosing an alternative. This framework is useful for exploring where adjustments in the parties' views of facts or values could lead to agreement on the best action, for suggesting where the acquisition of additional information to reduce uncertainty might lead to agreement, for developing contingent strategies that take advantage of the parties' differing views on probabilities, and for dovetailing dissimilar interests and capabilities into alternatives that offer joint gains. Maguire and Boiney (in prep.) illustrate these uses of decision analysis for resolving a dispute about management of an endangered species.

CASE STUDY

Study Area

I will illustrate some aspects of the combined decision analysis/dispute resolution framework using a planning effort that is in progress for the Chattahoochee National Forest in northern Georgia. The study area is 18,000 acres on the headwaters of the Chattahoochee River that was released from RARE II wilderness study ten years ago, but has received little active management since. It is bordered by two scenic highways, the Appalachian Trail, and an existing wilderness area. Part of the area is designated as a state wildlife management area. It is within a few hours' drive of three large cities and receives intense recreational use from more than 240,000 visitors a year. This pressure is causing environmental degradation, particularly in riparian zones, as well increasing conflict among user groups, which include fishermen, hunters, campers, horseback riders, bicyclists, hikers, wilderness enthusiasts, pleasure drivers, and local timber operators. These groups disagree about the best allocation of the area among national forest multiple use objectives, ranging from timber production to wilderness. During the planning process, 13,000 acres were nominated for wilderness designation, removing them from planning and management while the wilderness proposal is pending.

The Forest Service wanted to develop a management plan for the area that would both meet the needs of the various user groups and protect the environment. They assembled an interdisciplinary team of Forest Service employees, supplemented by representatives of the major user groups, to help identify issues of concern and propose alternatives for management.

Objectives/Criteria Hierarchies

The first step was to identify the interest groups and their objectives. These were assembled into a hierarchy of objectives, expanded into subobjectives that provide more concrete detail, culminating in specific criteria for measuring how well each subobjective is met. This process focusses attention on the interests of the parties, rather than on their positions and demands for management actions. A portion of the large objectives/criteria hierarchy that was synthesized from the Forest Service and user groups appears in Fig. 3.

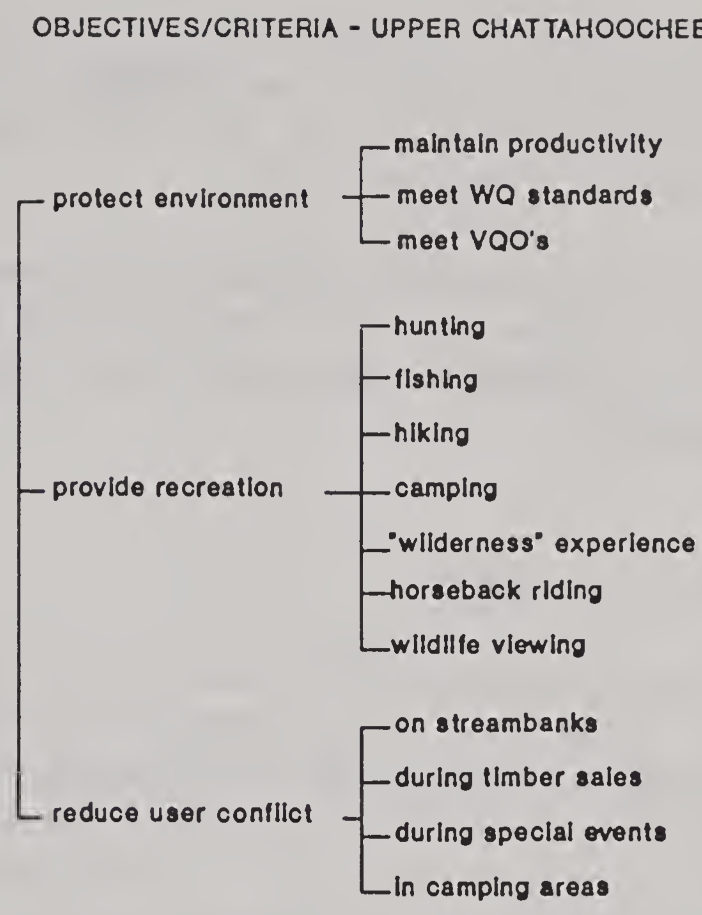

Fig. 3. Part of an Objectives/Criteria Hierarchy for the Headwaters of the Chattahoochee

Each of the subobjectives on the right-hand side was further broken into components until measurement criteria could be specified. Figure 4 illustrates one path through the hierarchy from major objective, through subobjectives, to measurement criteria.

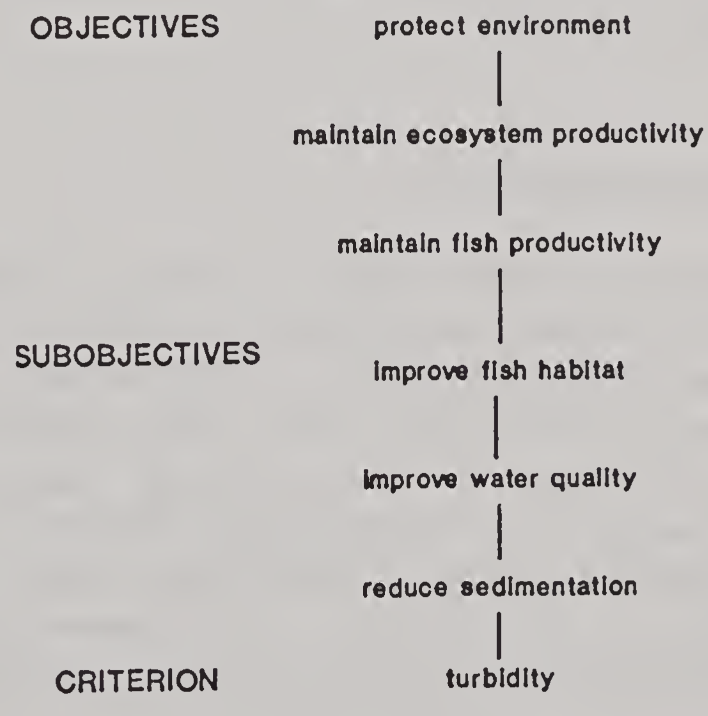

Fig. 4. Link Between Objectives, Subobjectives and Criteria

Proposing specific measurement criteria focusses attention on collecting data and making observations or model projections to support the analysis of competing management alternatives. It also directs the development of a monitoring scheme during the implementation phase of whatever plan is selected.

The remaining examples of the use of decision analysis and dispute resolution draw on the objectives/criteria hierarchy developed for the headwaters of the Chattahoochee, but because the planning process is ongoing and alternatives have only recently been proposed, these illustrations are hypothetical.

Representing Disagreements about Facts

One source of disputes about appropriate forest management is disagreement about how management actions and the natural and sociopolitical environment are likely to interact to produce results. One possible disagreement in the Chattahoochee case is whether loss of vegetation from streambanks or roadcuts is the most important source of sediment movement into streams. In the decision tree in Fig. 2, different parties will assign different probabilities to each of the random events branches, according to whether they believe streambanks or roadcuts to be more important, and will likely advocate different remedial actions as a consequence.

Displaying these probabilities and expected turbidity values explicitly helps communicate exactly where the disagreements lie and also helps to suggest joint fact-finding to help resolve such disagreements. In this example, the parties may be able to agree on measurements to be taken on sediment transport from streambanks and from roadcuts, or they might agree to a pilot scale trial of rehabilitating streambanks and roadcuts in order to resolve, or at least narrow, the differences in their probability models and in their recommendations for action.

Representing Disagreements about Values

The decision analysis framework is also useful for making explicit disagreements about values that can be a source of recommendations for different actions. Differences in relative preferences among various outcomes can be shown graphically using utility functions. In Fig. 5, Party 1 sees meeting state water quality standards for turbidity (marked by the tick on the x-axis) as being entirely satisfactory, with any further improvement in turbidity having no additional value. Party 2, on the other hand, sees merely meeting state standards as being of only modest value, with plenty of room for improvement. These differences can lead Party 1 to be content with management actions resulting in far more turbid water than would seem acceptable to Party 2.

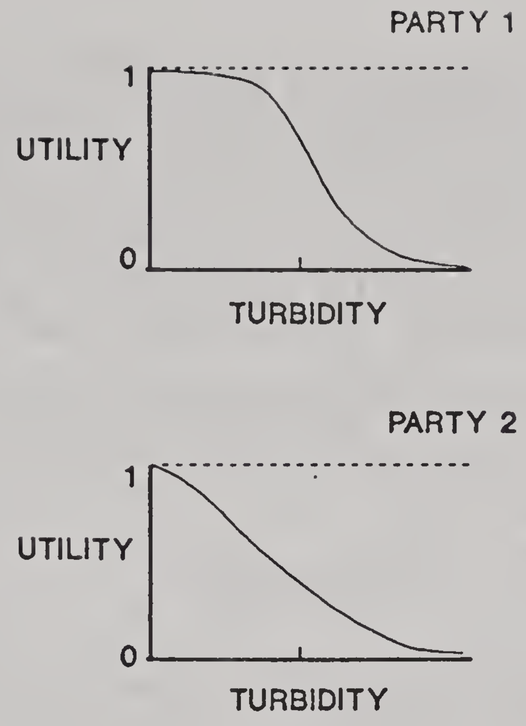

Fig. 5. Utility Functions for Turbidity Levels for Two Parties

Using Value Differences to Identify Satisfactory Alternatives

In Fig. 6, two parties have different priorities among multiple objectives.

Criteria

ALTERNATIVES	B/C RATIO	MBF	TURBIDITY	# FISH SAMPLED
A	0.7	30	10	150
• B	1.1	40	7	250
C	0.8	35	4	300
D	1.3	45	9	170

PARTY 1: MBF
B/C
⋮
TURBIDITY
FISH

PARTY 2: FISH
⋮
MBF

Fig. 6. Management Alternatives and Expected Values of Decision Criteria

Party 1 is most concerned with maintaining a modest flow of timber from the forest at a positive benefit-cost ratio and least concerned with water quality and fish populations. Party 2 is most concerned with the latter measures of environmental quality and least concerned with timber production and financial benefits. By displaying their priorities and preferences explicitly, it is easier for the parties themselves, as well as any intervenor, to suggest alternatives that offer something of value to each party. In the matrix shown in Fig. 6, alternative B seems most promising, offering relatively high levels of timber production at a favorable cost-benefit ratio, but also relatively low turbidity and high fish populations.

SUMMARY

Combining decision analysis with environmental dispute resolution offers the potential for better integration of public representation and technical analysis in national forest management. The first step in the combined framework, identifying the parties to the dispute and their interests, translates the interests of each party into specific objectives and criteria. Focussing from the outset on interests and objectives minimizes early polarization on positions or demands for action. Proposing specific measurement criteria for each objective emphasizes that the remaining negotiations are to focus on observable results, drawing from the best scientific information and analysis put forward by all parties. The measurement criteria shape the evaluation of alternatives by providing jointly agreed measures for each objective, which may, nevertheless, be valued differently by different parties, as expressed through their utility functions. Information on preferences and priorities among objectives can be used later in the analysis to make tradeoffs among conflicting objectives and to help craft combinations of actions that offer benefits to each party in the area that it values most and costs in the areas that it values least.

Explicitly representing each party's views on facts and values in the decision analysis clarifies the source of disagreements on appropriate management strategies, which can help devise means of resolving disagreements. Sometimes this can be done by collecting and reanalyzing existing information, using methods jointly approved by the various parties. Sometimes the parties can agree on an experiment or pilot study that can provide the information necessary to resolve disagreement. In some cases, the phenomenon in question is inherently uncertain (e.g., occurrence of catastrophic storms) and the parties disagree about the likelihood of these storms, but they can sometimes agree on a contingent management strategy, specifying what actions will be taken if a storm occurs and what will be done if there is no storm.

Disagreements about value are not generally amenable to negotiation, but they need not impede agreement on appropriate management. In fact, many of the strategies for formulating alternatives that offer joint gains depend on cleverly combining the dissimilar preferences, priorities, capabilities and risk attitudes of the disputing parties (Sebenius 1984). Representing these differences using utility functions helps to direct these negotiations.

Appealing to maximization of expected utility in the decision analysis offers a jointly accepted standard for evaluating management alternatives. Although each party will not assign the same utility to different results, and therefore may not prefer the same alternative, each uses the same decision rule on the expected utilities calculated from the probability and utility models. This makes each party's decision process more accessible and more understandable to the other parties and to any intervenor.

The sequence of steps in a combined decision analysis and dispute resolution framework fits nicely into the public participation and analysis requirements of NFMA and NEPA. The identification of parties and interests is part of the issues, opportunities and concerns portion of the NEPA process. Proposing alternatives that are responsive to the issues raised is also part of the NEPA process. The objectives/criteria hierarchy and the resolution of tradeoffs among conflicting objectives in decision analysis facilitates meeting the broadened mandate of national forest management under NFMA, NEPA and public pressure. The combined decision analysis and dispute resolution framework makes explicit and open to scrutiny a decision and negotiation process that may otherwise appear opaque and capricious. Obtaining a consensus on forest management helps ensure that the substance of the resulting plan will be defensible. Developing that consensus through an open and rational procedure ensures that the process is defensible as well. Among the long-term benefits of using this framework are not only forest plans that make the best use of available scientific information to meet user needs and protect the environment, but also better working relationships among the parties to national forest management for future plans and projects.

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